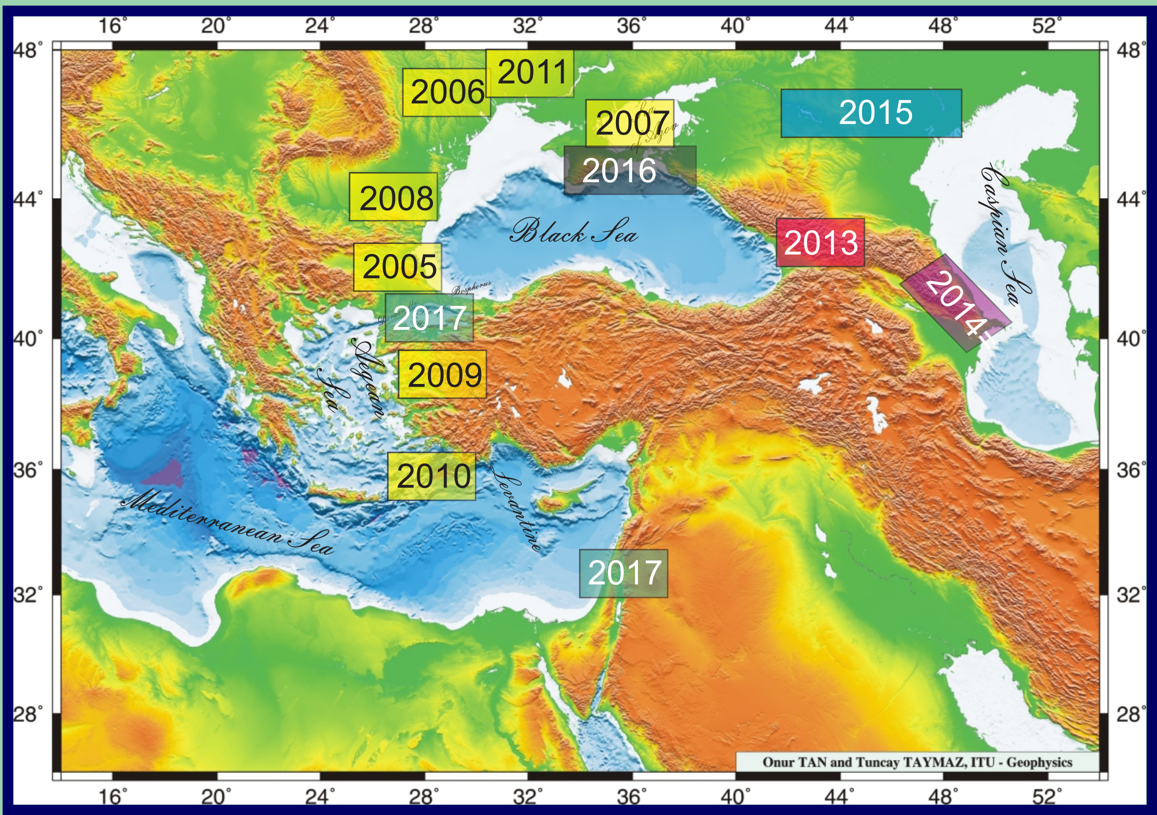
Geology Institute of the Azerbaijan National Academy of Sciences, Baku, Azerbaijan

12-20 October 2014

INTERNATIONAL GEOSCIENCE PROGRAMME



Proceedings of the Second Plenary Conference

IGCP 610 “From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary” (2013 - 2017)

http://www.avalon-institute.org/IGCP

IGCP 610 Second Plenary Conference and Field Trip, Baku, Azerbaijan, 12-20 October 2014

PROCEEDINGS

Organizers:

Geology Institute of the Azerbaijan National Academy of Sciences, Baku, Azerbaijan

Sponsors

UNESCO

IUGS

Geology Institute of the Azerbaijan National Academy of Sciences, Baku, Azerbaijan

Avalon Institute of Applied Science,

Geology Institute of the
Azerbaijan National Academy
of Sciences

Baku, Azerbaijan

PROCEEDINGS

IGCP 610 Second Plenary Conference and Field Trip

“From the Caspian to Mediterranean: Environmental Change and Human Response during the Quaternary”
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Baku ◆ Name of Publisher ? ◆ 2014

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AIMS AND SCOPE

The main goal of the IGCP 610 Project is to provide cross-disciplinary and cross-regional correlation of geological, archaeological, environmental, and anthropological records in order to (a) explore interrelationships between environmental change and human adaptation during the Quaternary, (b) create a networking and capacity-building structure to develop new interdisciplinary research initiatives, and (c) provide guidance to heritage professionals, policy makers, and the wider public on the relevance of studying the Caspian-Black Sea-Mediterranean Corridor ["CORRIDOR"] for a deeper understanding of Eurasian history, environmental changes and their relevance, and likely future impacts on humans.

The "CORRIDOR" is perfectly suited for these purposes. (1) It encompasses the large chain of intercontinental basins—the Caspian, Black (together called Ponto-Caspian), Marmara, Aegean, and Eastern Mediterranean (Levantine) seas—with their connecting straits and coasts. Here, sea-level changes are clearly expressed due to geographical location and semi-isolation from the World Ocean, which makes the "CORRIDOR" a paleoenvironmental amplifier and a sensitive recorder of climatic events. Periodic connection/isolation of the basins during the Quaternary predetermined their specific environmental conditions and particular hydrologic regimes, and thus, the area, and especially the Black Sea, represents a "natural laboratory" to study the responses of semi-isolated basins to GCC. (2) It has rich sedimentary and geomorphologic archives that document past environmental changes. (3) It has a substantial archaeological, anthropological, and historical record. In particular, it contains evidence for the transition from *Homo erectus* to *Homo sapiens*. The first appearance of a *Homo* species in the "CORRIDOR" is dated to the Lower Paleolithic, ca. 1.8 million years ago, at Dmanisi in Georgia. After this species migrated into the Ponto-Caspian area, human colonization of the region continued, major cultural and technological inventions (tools, hearths, dwellings, clothes, decorations, etc., as well as the origin of art, ideology, and ritual practice) ensued, and subsistence strategies were elaborated, enabling us to investigate multiple physical, social, and cultural responses of humans to global environmental change. (4) It is easily accessible for study.

To achieve the main goal and objectives, the Project will incorporate six dimensions, each addressed by integrating existing data and testing of hypotheses: 1. The geological dimension will examine the sedimentary record of vertical sea-level fluctuations and lateral coastline change. 2. The paleoenvironmental dimension will integrate paleontological, palynological, and sedimentological records to reconstruct paleolandscapes. 3. The archaeological dimension will investigate cultural remains. 4. The paleoanthropological dimension will study responses of different *Homo* species to environmental change. 5. The mathematical dimension will provide GIS-aided mathematical modeling of climate and sea-level changes, and human dispersal linked to paleoenvironmental variation that can be meaningfully compared with current global changes. 6. The geo-information dimension will grasp the "big picture" of geoarchaeological events over the duration of the Quaternary. Particular attention will be given to synthesizing the wealth of literature published in local languages, stored in archives, and largely unknown or ignored in the West.

Study sites will include the Caspian, Azov-Black Sea, Marmara, and Eastern Mediterranean. These sites are characterized by rich sedimentary, geomorphological, archaeological, paleoanthropological, and historical records providing a superb opportunity to assess the influence of climate and sea-level change on human development. It is expected that the project will allow us to suggest a groundbreaking, comprehensive theory about the influence of paleoenvironmental changes on human adaptive strategies during most of the Quaternary in the region of the Southern Eurasian seas.

There will be five or six Plenary Conferences and Field Trips in the following regions: 2013 – Georgia; 2014 – Azerbaijan; 2015 – Russia (Northern Caspian and Manych Outlet); 2016 – Crimea and Taman Peninsula (Russia); 2017 – Israel (Eastern Mediterranean) and Turkey (around the Sea of Marmara). They are scheduled for the third quarter of each year. Prior to each Conference and Field Trip, the Conference Proceedings and Field Trip Guide will be prepared. Each Plenary Conference will provide a forum for dialogue between multidisciplinary specialists in the Quaternary history of the "CORRIDOR" and other workers in related areas.

The Field Trips will follow the Plenary Meetings (Fig. 1). They will be focused on observation of geological characteristics of Quaternary stratotypes as well as key archaeological and paleontological sites. All of them are easily accessible for study and will be sampled during the Field Trips for further investigation in various laboratories around the world.

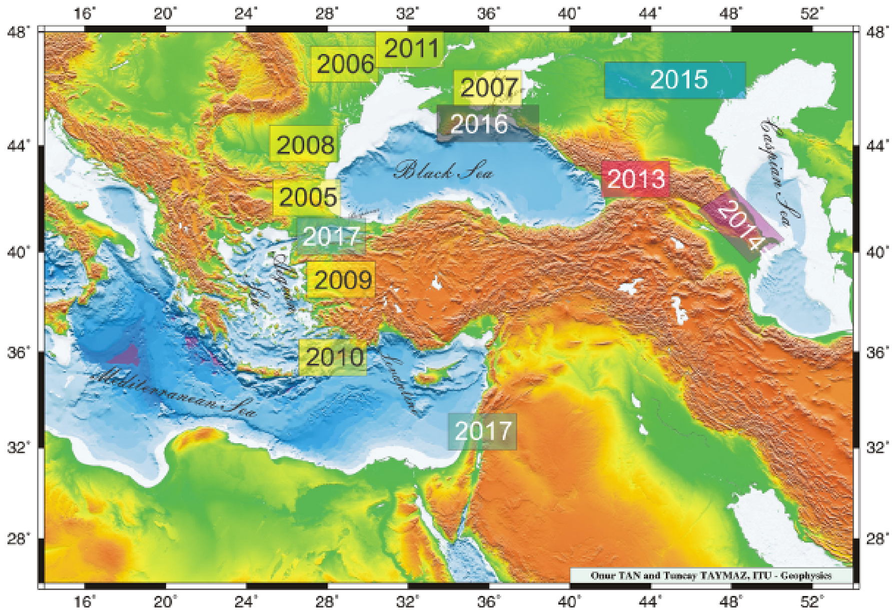

Figure 1. The Caspian-Black Sea-Mediterranean "CORRIDOR": in yellow are the locations of IGCP 521-INQUA 501 meeting and field trip sites (2005-2011); in other colors are sites to be studied by the present IGCP 601 Project: 2013 – Tbilisi, Georgia; 2014 – Baku, Azerbaijan; 2015 – Volgograd-Astrakhan' (Lower Volga), Russia; 2016 – Sevastopol (and the Taman Peninsula, Russia; 2017 – Haifa, Israel, and Istanbul, Turkey.

The Second Plenary Meeting and Field Trip will focus on the whole spectrum of Quaternary geological sequences exposed in the terraces and ridges of the Caspian region. This includes the stratotype of the Mountain of Bakinian stage (ca 600–450 ka BP) located in the suburbs of Baku on the Absheronian Peninsula; major exposures in the southwestern and central parts of the peninsula of Garagush mountain, Bakinskie Ushi, the village of Gezdek in the Shikhovo region, and in the Yasamal' valley. This includes outcrops of the Quaternary deposits at Garamaryam and Turianchay in the Ajinour region. The Neogene-Quaternary boundary as well as the Matuyama-Brunhes Reversal with Olduvan and Jaramillo episodes will be traced. The archaeological sites in Gobustan with its famous petroglyphs of Mesolithic age will be observed. Plans include visits to some archaeological and historical places in Baku: the Shirvanshakh Palace constructed during the period from the XIIIth to the XVIth century; the Maiden Tower (the most mysterious monument of Baku) of which the unique construction has no analogs in the East. The Palace complex and Maiden Tower are included in the UNESCO list of World heritage sites.

WELCOME

On behalf of the Organizing and Executive Committees as well as the Geology Institute of the Azerbaijan National Academy of Sciences, Baku, Azerbaijan, and Avalon Institute of Applied Science, Canada, we are delighted to welcome you to the IGCP 610 Second Plenary Conference and Field Trip being held on 12–20 October 2014 in Azerbaijan.

This conference is the second in a series of IGCP 610 Plenary Conferences and Field Trips. It will continue to will bring together multidisciplinary scientists from all over the world in order to enhance West-East scientific dialogue by providing a supportive background for collaboration regarding the correlation and integration of discoveries on the influence of climatically/tectonically induced sea-level changes and coastline migration on humanity. This is an area of strategic importance for Europe and Asia.

The Second Plenary Conference and Field Trip has been organized and sponsored by the Geology Institute of the Azerbaijan National Academy of Sciences, Baku, and the Avalon Institute of Applied Science, Winnipeg, Canada, with very moderate financial contributions from UNESCO and IUGS.

We are happy to welcome to Azerbaijan distinguished specialists and students in the Humanities, Earth, and Life Sciences from Azerbaijan, Bulgaria, Georgia, Germany, Italy, Romania, Russia, Turkey, UK, and Ukraine.

We wish you a very pleasant stay in Azerbaijan.

Sincerely,

Organizing and Executive Committees of IGCP 610 Second Plenary Meeting and Field Trip

VENUE

The conference will be held in Baku under the auspices of the Geology Institute of the Azerbaijan National Academy of Sciences (www.gia.az). Baku is the capital and largest city of Azerbaijan, as well as the largest city on the Caspian Sea and in the Caucasus region. Baku is located 28 m (92 ft) below sea level, which makes it the lowest lying national capital in the world. Baku is also the largest city in the world located below sea level. It lies on the southern shore of the Absheronian Peninsula, which projects into the Caspian Sea. The city consists of two principal parts: the downtown area and the old Inner City (21.5 ha). Baku's urban population is estimated at just over two million people. Officially, about 25 percent of all inhabitants of the country live in Baku's metropolitan area.

Baku is divided into eleven administrative districts (raions) and 48 townships. Among these are the townships on islands in Baku Bay and the town of Oil Rocks built on stilts in the Caspian Sea, 60 km (37 mi) away from Baku. The Inner City of Baku along with the Shirvanshah's Palace and Maiden Tower were inscribed as a UNESCO World Heritage Site in 2000. According to the Lonely Planet's ranking, Baku is also among the world's top ten destinations for urban nightlife. The city is the scientific, cultural and industrial center of Azerbaijan. Many sizeable Azerbaijani institutions have their headquarters there, including SOCAR, one of the world's top 100 companies, and others. The Baku International Sea Trade Port, sheltered by the islands of the Baku Archipelago to the east and the Absheronian Peninsula to the north, is capable of handling two million tons of general and dry bulk cargoes per year.

The urban landscape of Baku is shaped by many communities. The religion with the largest community of followers is Islam. The majority of the Muslims are Shia Muslims, and the Republic of Azerbaijan has the second highest Shia population percentage in the world after Iran. Zoroastrianism had a long history in Azerbaijan, evident in sites such as the Fire Temple of Baku or ceremonies like Nowruz, along with Manichean. The city's notable mosques include Juma Mosque, Bibi-Heybat Mosque, Muhammad Mosque, and Taza Pir Mosque. There are some other faiths practiced among the different ethnic groups within the country. By article 48 of its Constitution, Azerbaijan is a secular state and ensures religious freedom. Religious minorities include Russian Orthodox Christians, Catholic Levantines, Ashkenazi Jews, and Sufi Muslims.

Baku has a subtropical, semi-arid climate with warm and dry summers, cool and occasionally wet winters, and strong winds all year long. However, unlike many other cities with this climate, Baku does not see extremely hot summers. This is largely because of its northerly latitude and the fact that it is located on a peninsula on the shore of the Caspian Sea.

The conference will be held under the auspices of the Geology Institute of the Azerbaijan National Academy of Sciences (www.gia.az). The Institute structure includes 24 research departments, the National Data Center of Azerbaijan (established in 2003 on the initiative of the Preparative Committee of Comprehensive Nuclear Test Ban Treaty Organization, or CTBTO), Centre of common use of the analytical devices and equipment, and the Natural History Museum named after H. Zardabi. The Institute staff comprises 230 researchers, including 3 academicians of ANAS, 8 corresponding members of ANAS, 35 doctors of science, and 85 candidates of science. The main directions of investigation are: geology and oil-and-gas geochemistry, oil-and-gas field development, petrology and metallogeny, regional geology, and earth physics.

ACKNOWLEDGMENTS

We gratefully acknowledge the support and hospitality of the Geology Institute of the Azerbaijan National Academy of Sciences, Baku, Azerbaijan, for hosting the IGCP 610 Second Plenary Meeting and Field Trip, and providing us with their facilities to convene this conference.

Support has also been received from the Avalon Institute of Applied Science, Canada. Financial contributions to underwrite the travel costs for scientists from developing countries and countries in transition were kindly provided by UNESCO, IUGS, and IGCP.

We are indebted also to Prof. Elmira Aliyeva for her extraordinary efforts in organizing the conference and field trips. Particular appreciation is extended to Prof. Talat Kangarli, Prof. Dadash Huseynov, Prof. Ilyas Babayev, Dr. Lala Aliyeva, Nailya Kerimova, Sevinj Shiraliyeva, and Tofik Rashidov for arranging the Field Trips around Baku and preparing the Field Trip Guide.

We gratefully recognize the assistance of Prof. Allan Gilbert together with Prof. Dr. Valentina Yanko-Hombach for editing and layout of the Conference Proceedings.

To the Scientific Committee, we offer sincere thanks for evaluating submissions and managing the abstract review process.

The Scientific Committee, in turn, wishes to thank the anonymous reviewers for their efforts in providing useful comments on submitted abstracts.

For her prompt action, we extend our appreciation to Dr. Irena Motnenko for regularly updating the IGCP 610 website.

We are also very grateful to the journal *Quaternary International*, which has kindly invited us to publish the Baku conference proceedings within their pages just as it did for previous IGCP 521-INQUA 501 and IGCP 610 conferences.

Valentina Yanko-Hombach

SCHEDULE

12 October 2014

ARRIVAL AND REGISTRATION

Registration: 12 August 14.00-18.00	Geology Institute of the Azerbaijan National Academy of Sciences, 29A H. Javid av., Baku, AZ1143, Azerbaijan Tel: +994125100141, Email: e_aliyeva@gia.ab.az

12 October 2014

ICE-BREAKING PARTY

19.00	"Ailevi restaurant" located at the Fountain square, Baku

13-14 October 2014

TECHNICAL SESSIONS

9.00-18.00	Geology Institute of the Azerbaijan National Academy of Sciences, 29A H. Javid av., Baku, AZ1143, Azerbaijan

15-20 October 2014

FIELD TRIPS

15 October 2014

Field Trip 1

9.00-18.00 Depart from Baku (meeting of all participants near the Maiden Tower). Return to Baku to the same hotel as you booked.	Excursion to Old City: the Maiden Tower and Shirvan Shakh Palace. Exposures of Absheronian stage sediments. The Garagush mountain The Bakinskie Ushi (overnight accommodations in Baku).

16 October 2014

Field Trip 2

9.00-18.00 Depart from Baku and return to Baku to the same	Stratotype of the Mountain of Bakinian stage, examples of the rapid Caspian Sea level changes in the Pleistocene successions. Archeological reserve Gobustan. Mud volcano Dashgil (overnight accommodations in Baku).

hotel as you booked.

17 October 2014

Field Trip 3

8.00-18.00 Depart from Baku to Lagich.	Western Azerbaijan and Great Caucasus. Continuous outcrop of the Quaternary continental sediments of Ajinour (outcrop Padar "windows"). Excursion in the historical village Lagich (overnight accommodations in the historical village Lagich).

18 October 2014

Field Trip 4

9.00-18.00 Depart from Lagich to Gabala.	Western Azerbaijan and Great Caucasus. Exposure of the Quaternary continental and marine sediments of Ajinour (outcrop Turianchay) (overnight accommodations in the maintain resort Gabala). **Conference dinner in the Sky restaurant.**

19 October 2014

Field Trip 4

8.00-18.00 Depart from Gabala - return to Gabala.	The First Christian church in the Caucasus, I century**.** Khan palace in the historical town Sheki. Historical museum in Sheki. Western Azerbaijan. Reference outcrop of the marine Baku stage sediments Bozdag (overnight accommodations in the maintain resort Gabala).

20 October 2014

Field Trip 5

8.30-15.00 (excursion) Depart from Gabala to Baku around 10:30 by conference bus after excursions; arrival in Baku around 15.00.	Archaeological sites: excavations of ancient towns Selbir and Gala, I-XVIII centuries. Archeological museum in Gabala (overnight accommodations in Baku for those who depart to respective countries on October 21).

20-21 October 2014

DEPARTURE FROM BAKU TO RESPECTIVE COUNTRIES

PART I. IGCP 610 PROGRESS REPORT (2013)

Yanko-Hombach, V. [1, 2]

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1. Website address(es) related to the project

http://www.avalon-institute.org/IGCP610/ - main
http://www.geogr.msu.ru/science/projects/unesco/
http://www.geoecomar.ro/website/proiecte.html
http://archaeology-ethnology.onu.edu.ua/?p=1096
https://www.facebook.com/groups/180481035443572/
http://vk.com/album115218532_181815723

2. Summary of major past achievements of the project

The project commenced on 1 April 2013. Since that time, it has served as a focal point for correlation of scientific data obtained by research projects dealing with environmental change and human response in a variety of settings from the Caspian to Mediterranean seas during the Quaternary. In general, nine months of IGCP 610 activity have been carried out in a strict agreement with the Working Plan [http://www.avalon-institute.org/IGCP610/work_plan.php]. The one exception was the creation of the GIS-aided Interactive Data Base that was postponed until the end of 2015.

The following achievements have been obtained by IGCP 610 participants so far:

- Establishing the multidisciplinary team of scientists working on the project. The list includes more than 200 specialists from 18 countries, about 75% of whom are from developing countries surrounding the Caspian-Black Sea-Mediterranean Corridors. Developing world participation has been high in IGCP 610 activities, both through the direct conduct of scientific activities and through participation in the conference.
- Creating a regularly updated IGCP 610 website and mailing list of participants that contains 1054 addresses.
- Disseminating the basic ideas, main activities and achievements of the Project via social networks (Facebook for English and non-English-speaking audience, Вконтакте – for the mostly Russian speaking audience) in order to bring together professionals, representatives of public bodies, and the broader public to promote further studies within the framework of the IGCP 610 Project.
- Organizing the First Plenary Meeting and Field Trip of IGCP 610 in Georgia.
- Publishing a peer-reviewed Conference Proceedings (183 pages) and the Field Trip Guide. The former contains 60 publications written by 151 authors from 19 countries.
- Establishing the Reference List of main publications on Project subjects.
- Correlating the Regional Stratigraphic Scales.
- Collecting regional Paleogeographic and Geological maps.
- Field and laboratory work (for details see Chapter 3).

3. Achievements of the project (year 2013 only)

3.1. List of countries involved in the project:

Eighteen countries (all active in 2013): Azerbaijan, Belgium, Bulgaria, Canada, Georgia, Germany, Israel, Italy, France, Kazakhstan, Romania, Russia, The Netherlands, Slovakia, Turkey, UK, Ukraine, and USA

3.2. General scientific achievements and social benefits

- Revision and integration of scientific materials available in a variety of languages in order to identify the main results of work to date as well as gaps in our knowledge, and to prepare an extensive Reference List. This task is crucially important, as most data are published in Russian and not easily accessible for foreigners.
- Revision of the taxonomy and ecology of recent and fossil mollusks, foraminifera, and ostracoda [MFO] used for ecostratigraphic and paleoenvironmental reconstructions.
- Catalogue of SEM pictures of MFO as well as spore and pollen from Pleistocene-Holocene sediments of the Ponto-Capian region.
- Development of a common geochronological frame necessary for correlating major events in human prehistory and history with global environmental changes.

In the Black and Marmara Sea region:

- Study of the Eopleistocene geological sequence of Tsvermaghala Mountain that represents a stratotype of the Gurian Chauda; it possesses a thickness exceeding 1000 m deposited prior to the Matuyama-Brunhes Reversal (i.e., 780 ka BP) as well as archaeological sites of Lower to Upper Paleolithic age that include Dmanisi, Mashavera Gorge, Tetritskaro, Tsalka-Bedeni Plateau, Faravani Lake, Akhalkalaki, Diliska, Chiatura, Bondi Cave, Undo Cave, Djruchula Gorge, as well as the Neolithic site Samele Cave and the Medieval-Roman site Vardzia Cave.
- Procuring and processing data on prehistoric cultures. Among the most outstanding results of recent work has been: defining the pace and trajectories of different ways of endemic movements arriving in Southeastern Europe; the development of a new cultural formation in the region around Marmara that would be a new core for further movement of early farming communities into Europe; defining the interaction of the migrant farmers with local hunter-fisher communities particularly in the region around Istanbul.

In the Caspian region:

- Detailed study of chocolate clays in the Middle and Lower Volga region that have enabled the discovery of a direct correlation between their occurrence and morphology of relief. Material collected by the expedition is currently being studied using palynologic, lithologic, geochronologic, and malacofaunal and micropaleontologic methods.
- Developing of a Holocene stratigraphic scale for the Iranian coast of the Caspian Sea.
- Obtaining new material for paleogeographic reconstructions of the Caspian basin from biostratigraphic analysis of five boreholes recovered in the North Caspian. Two marine strata that are absent on the coasts were discovered. Also, obtained a series of new radiocarbon dates for sediments and events of the late Pleistocene in the Caspian.
- A key geological section "Otkaznoe" located in the Tersko-Kumskaya lowland has been studied by paleomagnetic, palynologic, and microteriologic methods. Detailed reconstructions of landscape and climate evolution in the NW Capsian region were performed for the Pleistocene and Holocene.

In the Ponto-Caspian region:

- Comparative analysis of environmental evolution enabled a reconstruction of the last climatic macrocycle (MIS 5-1).
- Social benefits: IGCP 610 activity has encouraged East-West dialogue by integrating eastern and western scientists into an international R&D community through scientific collaboration,

workshops, and annual meetings. As a result, eastern scientists have obtained access to western laboratories and advanced scientific methods while western scientists have had access to a vast amount of material stored in the former USSR and Eastern Bloc archives or published in local languages.

3.3. *List of meetings with approximate attendance and number of countries*

1. IGCP 610 First Plenary Meeting and Field Trip, 12-19 October 2013, Tbilisi, Georgia: 151 contributors from 19 countries, 66% of whom are from developing countries (Fig. 1).

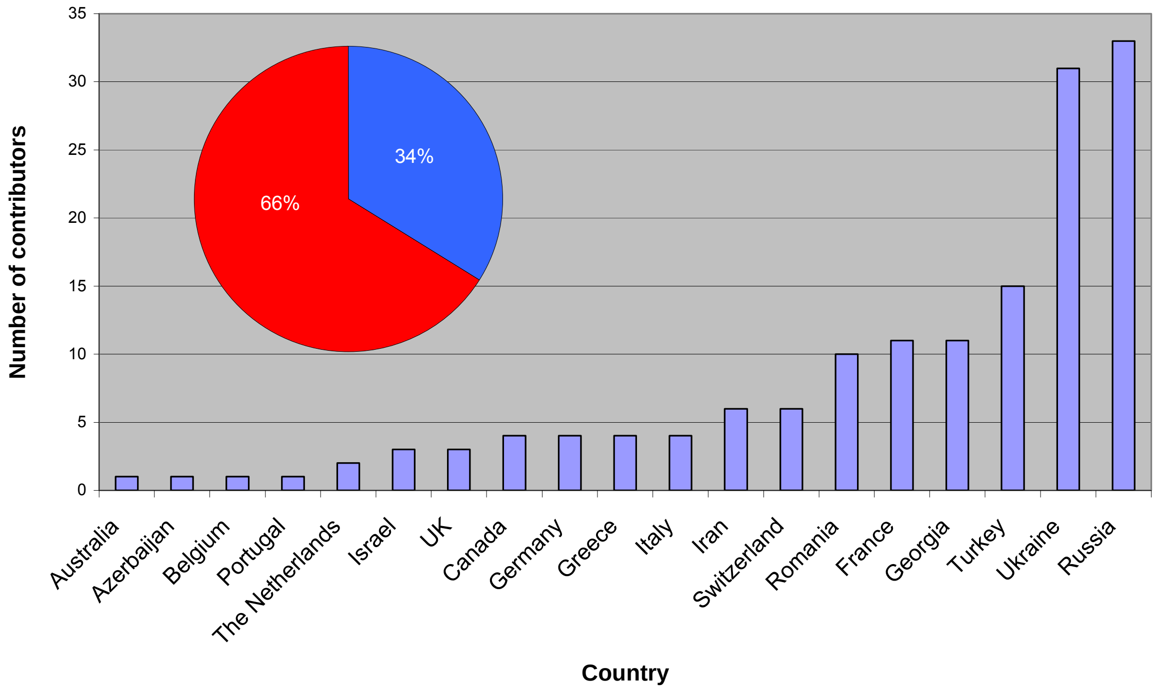

Figure 1. Number of countries and contributors to IGCP 610 First Plenary Conference and Field Trip. The circle shows the percentage of scientists from developing (red) and developed (blue) countries, respectively.

- IGCP 610 participated as the main partner in a workshop at Sozopol attended by 22 scientists (archaeologists, geologists, marine scientists) from Turkey and Bulgaria.
- IGCP 610 was represented at the International Conference “Under the Sea: Archaeology and Palaeolandscapes”, 23–27 September 2013, Szczecin, Poland..

3.4. *Educational, training or capacity building activities*

So far IGCP 610 activities: (1) enabled participants to visit relevant sites in the Black Sea part of the study area under the guidance of local experts with on-site discussion of scientific issues; (2) formed a platform for young undergraduate and postgraduate students to benefit from international exposure and interaction with scientists from different parts of the world and varied specialties (for example, a project involving geomorphological study of the Kolkheti lowlands has been initiated between Illia State University and the University of Cologne, Institute of Geography by young scientists: Dr. Kelterbaum and Mr. Sukhishvili); (3) encouraged students to take new educational courses related to project topics, and to start working within a multidisciplinary approach that has been intensively discussed during the conferences; (4) involved about 25 students from Georgia in the organization of the First Plenary Meeting and Field Trip in Georgia in 2013, thus providing them with experience to develop their organizational skills and abilities in order to cultivate traditions of “European style” scientific fora as well as scientific discussion and informal meetings. This also promoted their interest in particular specialties and motivated them to learn foreign languages in order to improve communication skills with western colleagues; (5) promoted a multidisciplinary approach in paleoenvironmental studies, which has encouraged students in geology to take archaeological courses and vice versa. This stimulated teachers to modify their curricula for undergraduate and graduate students (e.g., "Paleogeography," "Paleoecology," "History of the cultural exploration of the Northwestern Pontic region," "Geoarchaeology of the Stone Age"); (6) promoted the preparation of several MA and PhD theses on subjects within the IGCP 610 project; (7) promoted the establishment of direct contacts between western and eastern youth, creating the background for better understanding of modern priorities in the developing world of science and humanities; (8) exposed the younger generation in developing countries to new analytical techniques and state-of-the-art data interpretation in the field of sustainable development and environmental risk protection, as well as human cultural development; (9) informed the wider public about the evolution of the environment during the last climatic cycle; (10) provided consultations on stratigraphy, paleogeography, palynology, macro- and microfauna to specialists from Russia, Azerbaijan, Ukraine, Iran, Bulgaria, the Netherlands, and Georgia.

3.5. Participation of scientists from developing countries, and in particular young and women scientists

Out of about 150 scientists contributing in the project, most of them attended the meeting and field trip in Tbilisi (Fig. 2). About 50% are female scientists; 40 participating scientists are young, among whom 35% are female. About 66% of participants are from developing countries.

Figure 2. Group photo from the IGCP 610 First Plenary Meeting and Field Trip, Ilia State University, Tbilisi, Georgia, 2013..

3.6. List of most important publications (including maps)

See Annex 1.

3.7. Activities involving other IGCP projects, UNESCO, IUGS, or others

There are several projects closely related to IGCP 610 in which participants work. They are as follows:

Project № 11-05-00093 "Caspian region: Peculiarities of development of the environment under climate and sea level change," supported by the Russian Foundation for Fundamental Research.

Project № 12-05-01052 "Evolution of the relief of the Azov and Black Sea coast, climate, and sea level change: Comparative analysis and chronology of environmental processes for the last 20 ka," supported by the Russian Foundation for Fundamental Research.

Project № 13-05-00086 "Pont-Manych-Caspian oceanographic system in the late Pleistocene: Systematics and correlation of events, evaluation of character and degree of interaction, paleogeographic consequences in the region," supported by the Russian Foundation for Fundamental Research.

Project № 13-05-00242 "Radioisotope stratificationof age and synchronization of the Quaternary deposits of the Ponto-Caspian," supported by the Russian Foundation for Fundamental Research.

Project № 13-05-00625 "Peculiarities of the evolution of relief in the Northern Caspian region in the late Pleistocene: Main stages of the development, chronology, and correlation with climatic rhythms in the Black Sea-Caspian region," supported by the Russian Foundation for Fundamental Research.

Project № 12-05-31281 "Khvalynian epoch in the history of the Caspian region: Paleoclimates and environmental evolution," supported by the Russian Foundation for Fundamental Research.

Project WAPCOAST "Water pollution prevention options for coastal zones and tourist areas: Application to the Danube Delta front area," supported by the BLACK SEA ERA.NET - Pilot Joint Call "Networking on Science and Technology in the Black Sea Region."

Project MAREAS "Black Sea Joint Regional Research Centre for Mitigation and Adaptation to the Global Changes Impact," Joint Operational Programme "BLACK SEA 2007–2013."

Project № Ф28/428-2009 "Northern Black Sea Region under GCC: environmental changes during the last 20 ka and forecast for the present century," supported by the Ukrainian Foundation for Basic Research and the Russian Foundation for Fundamental Research.

Project ECOST-MEETING-TD0902-090310-001280 SPLASHCOS "Submerged Prehistoric Archaeology and Landscapes of the Continental Shelf."

4. Activities planned

4.1. General goals

Efforts go on: (1) to maximize IGCP 610 exposure via diffusion of results in key international journals and updates of our web pages to ensure wide accessibility and increased interactive potential for project participants, the scientific community at large, relevant agencies, and the public; (2) to consolidate scientific achievements as a basis for developing a future strategy; (3) to continue to augment the funding base with upcoming and submitted research proposals through various funding agencies; and (4) to publish a special volume of *Quaternary International* devoted to the achievements of IGCP 610.

4.2. Tentative list of specific meetings and field trips with identification of participating countries

The Second Plenary Meeting and Field Trip will be held in Azerbaijan on 12–20 October 2014 and will be hosted by the Geological Institute of the Azerbaijan Academy of Sciences. Contributors will be from the following countries: Azerbaijan, Belgium, Bulgaria, Canada, France, Georgia, Germany, Greece, Iran, Italy, Romania, Russia, The Netherlands , Turkey, UK, Ukraine, and USA.

5. What tangible improvements has your project obtained? (Besides publications, we are interested to hear about improvements to research, scientific contacts, policy implications, etc).

Within the framework of the Project, students of archaeology and geoarchaeology at the BA, MA, and PhD level have been taking an active part in training, developing the capacity to run projects, work in the field, and analyze material. There are also a number of post-doc participants taking part in various installments of our project. Usually, there are more female participants than males, as most of our students are female. Besides, IGCP 610 activities, including the First Plenary Meeting and Field Trip in Georgia, promoted the establishment of direct contacts between western and eastern scientists, creating the background for better understanding of modern priorities in the developing world of science and humanities.

6. What kinds of outreach and training has your project undertaken? Please describe how this project specifically benefited women scientists, young scientists and/or scientists from developing countries.

See Part 3.4 for details.

7. What kind of public information (media reports, etc) has your project generated? And how do you evaluate their impact?

The media broadcast of IGCP 610, in particular the First Plenary Meeting and Field Trip that was held in Tbilisi, Georgia in 2013, attracted a lot of attention to the Project. Its activity was broadcast by the First Georgian Channel as well as a series of publications in periodicals for the mass media. A series of video films devoted to professional descriptions of the most prominent archaeological and geological sites of the Caucasian part of study region have been produced. All together, these contributed to the dissemination and popularization of IGCP 610 ideas, in particular, the preservation of human heritage by re-evaluating and clarifying existing archaeological questions to arrive at a better understanding of the human response to environmental change in order to improve human living conditions, sustainable development, and wise management of the Earth as a human habitat.

8. Attach any information you may consider relevant

Annex 1. Selected references published in 2013 (or in press) by IGCP 610 participants.

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PART II. PROCEEDINGS

Late Pleistocene-Holocene Caspian Sea level and climate changes

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Keywords: Caspian Sea high stand, low stand, Kura river delta, progradational and retrogradational cycles

High resolution studies on the new core and seismic data from the Kura River delta in the southwest Caspian Sea has provided deep insight into its late Pleistocene-Holocene history, enabling characterizations of short-term climatic variations and an improving of the Caspian Sea level curve. The data display several phases of delta retrogradation during the Caspian Sea highstands, interrupted by erosional phases during lowstands, recognizable in the seismic profiles as prominent reflectors. The first phase is represented by coarse sands with numerous shell fragments encountered at the base of the deepest well A at the subCaspian depth of 34 m. The data obtained allow us to assume that sand deposition took place during the late Pleistocene Caspian lowstand (24–25 ^{14}C ky BP) (Sequence 1).

Overlying dark reddish-brown sandy shales (interval 3034 m) were deposited during the time interval 18–23.7 ky BP (Atelian regression), which corresponds to the last glacial phase (Lunkkaa et al., 2001; Svitoch, 2013). These sediments are characterized by a lack of, or very rare fresh-brackish water mollusks (*Dreissena*) in the lowermost portion, and enriched in Fe_2O_3 and MnO suggesting sedimentation in the continental environment. We assume a deep Caspian Sea regression in the late Pleistocene (1825 ky BP) with the sea level falling to 102 m (Svitoch, 2013).

The subsequent warming recorded in the peaks of warm temperature and subtropical palynomorphs was accompanied by a sea-level rise and accumulation of grey shales with abundant mollusk and ostracod shells (core interval 25–30 m). The deep Mangyshlak regression at the beginning of the Holocene is recognized in the core samples as peat deposits or shallow water grey sandy shales with sand laminae and shallow water ostracods (interval 21–25 m) (Sequence 2). Recovered palynomorphs display cool temperature and a peak in halophytes. The sea level was gradually falling from –92 m (12 ky BP) to –96.5 m (9.24 ky BP).

The overlying Kura delta's Holocene sediments consist of a 20 m thick interval of thinly bedded silty clays and laminated dark grey clays. Locally, sand and shell-rich horizons occur.

The data have given concise insight into the development of the delta during the last ~10000 years. They show several phases of delta retrogradation during the Caspian Sea highstands, interrupted by erosional phases during lowstands, recognizable in the seismic profiles as prominent reflectors. The first phase is represented by reddened fluvial clays (Sequence 1), possibly affected by soil formation during a lowstand at –90 m absolute depth and dated at 12000 BP. These are overlain by several meters of laminated clays and silts, ^{14}C dated at 9240–5920 BP (Sequence 2). This succession is truncated by a prominent reflector bounding Sequence 3 (modern delta dated at 1400 BP consisting of thin laminated clays). Sequence 3 consists of four progradational and retrogradational phases of a higher order corresponding to: (1) a lowstand at about –48 m absolute depth and correlated with the 11th century Derbent Regression, (2) laminated deltaic clays and silts, passing locally to organic clays with fluvial diatom assemblages, (3) an erosional event, related to a lowstand in the 16th century, (4) The last 200 years deposited succession. The onshore delta consists of progradational sequences of channel-levee sands and floodplain silts and clays deposited during gradual sea-level fall and overlain by clays and silts reflecting the last phase of rapid sea-level rise since 1977. Overall sedimentation rates in the delta determined by ^{210}Pb methods range between 1.5–3.0 cm/year.

Data on O and C isotope composition of ostracod shell carbonate as well as Ca/Mg, Sr/Ba ratios therein testify to significant climate and basin salinity changes throughout the Pleistocene-Holocene. They provided us with a unique opportunity to characterize short-term climatic cyclicity, which was the major lake-level control.

The applied multi-component demonstrates a strong influence of climatically driven rapid fluctuations of the Caspian Sea level on stratigraphic architecture and faunal assemblages in the Pleistocene-Holocene succession..

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Dynamics of change in mountain ecogeosystems under the influence of natural-destructive phenomena (an example from the Major Caucasus)

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Keywords: mountain ecosystems, dangerous exodynamic processes, Alpine-Himalaya mobile belt

Over the last decades, there has been increasing interest in the problem of estimating the risk of natural and anthropogenic catastrophic phenomena that could have a huge impact on stable ecological and socio-economic development in mountain ecosystems. Occurrences of destructive phenomena are caused by extreme environmental events in combination with the consequences of traditional natural resource development. Exogeomorphological negative consequences demand a fast reaction and intervention. It is necessary to note that among the natural risks, a principal one involves dangerous and catastrophic natural-destructive phenomena because of the impossibility of obtaining reliable forecasts on the time and place of their occurrence. In this connection, the tendencies of development to incur dangerous exodynamic processes have become the major indicator of an ecological situation in mountain regions. The influence of catastrophic processes on the natural ecology of a territory is usually negative, sometimes bringing full physical destruction of separate components of a landscape and limiting internal communications within geosystems. Thus, catastrophic phenomena can result from the accumulation within geosystems of the consequences of irreversible influences from extreme processes, which disturb the condition of dynamic balance within a landscape. For geosystems possessing a delicate dynamic balance, a catastrophic phenomenon acts as a triggering mechanism for a subsequent and sometimes full destruction. Hence, diagnosing adverse situations and estimating degree of risk will help to avoid danger ahead of time, reduce damage, and also define necessary protective actions and specific ways of managing risk (Alizade and Tarikhazer, 2010).

Intensely dangerous exodynamic processes are influenced by various factors connected with the geologic-geomorphological structure of a territory as a whole as well as features of its relief. Dangerous exodynamic processes are characterized by their suddenness of occurrence, relatively short duration of development, and their large dynamic loading, causing their destructive action. Dangerous exodynamic processes, basically, are more likely in highly dissected areas with significant relief and abrupt slopes. For the majority of them, the constancy of the place and the seasonal recurrence of such displays is characteristic.

This work is devoted to the analysis of the natural and anthropogenic preconditions causing the intensity of ecogeomorphological processes of a young range of the Alpine-Himalaya mobile belt—the Major Caucasus. The Major Caucasus in its tectonic relations corresponds to the interplate zone, actively formed in recent times along a zone of collision between the Scythian, Transcaucasian, and Iran-Anatolia microplates. The highland is characterized by a deep partition in relief, the extreme steepness of slopes (25° and greater), and considerable slopes on the river valleys, which together with a difficult geological structure, high (8–9 points and more) seismicity, and wide and intensive development defines exodynamic processes. Under conditions of sharply dissected relief, high seismicity, unstable cover slope deposits, various granulometric structures, the hydrothermal conditions encourage development of all kinds, yet slope processes create an ecologic-geomorphological risk of events of catastrophic character, such as snow avalanches, mud flows, landslips, collapses, etc. As a whole, negatively influential and dangerous exodynamic processes have expanded in degree of intensity of their display over the last decades.

Intensive development of the Alpine meadows over the last years had led to sharp strengthening of the fluvial-glacial and gravitational processes. This has increased the frequency of avalanches, the formation of landslips, thawing and movement of mountain glaciers at the tops of Shahdag, Bazarduzi, and Tufandag, etc. Avalanche processes are observed in high-mountain and middle-mountain belts of the Major Caucasus in March-April when solar radiation increases. Avalanches are typical of the abrupt slopes of ridges and their tops, as on the mountains Tufandag, Bazarduzi, Shahdag, Gyzylgaya, and Babadag, avalanche downslope leaving taluses and collapses, etc. They occur often and in considerable quantity, causing substantial damage to the economy, blocking mountain roads, bridges, buildings, and other engineering-geomorphological constructions. As a result, there is an active degradation of unstable geocomplexes, characteristic for abrupt slopes of the Major Caucasus.

Deforestation was the reason behind the formation of mud flows and landslips within the Major Caucasus. Earth flows (mud-stone and mud flows) are characteristic of all high-rise belts of the region: high-mountain pools in the rivers Mazymchay, Belokanchay, Katexchay, Talachay, Muxaxchay, Kishchay, Shinchay, Damiraparanchay, Girdymanchay, Agsuchay, Gudialchay, Djimichay, Babachay, and Gusarchay, etc. Their concentration around river pools is typical of zones of anthropogenic influence on geosystems of these regions. Each river valley differs in the frequency of passage, force, and type of mud flows. The territory of the Major Caucasus is among most mud flow-damaged areas by quantity of flow pools, frequency of passage of various earth flows, their capacity, volume of the flow material exposures, and complexity of formation conditions. Earth flows are characteristic of all high-rise belts of the Major Caucasus, but the most typical are mud, stone, and mud-stone flows on the southern slope of the Main Caucasian ridge. The Kurmuhchay-Kishchay area covers pools of the rivers Kurmukhchay, Shinchay, and Kishchay. For example, the relief of pools of the rivers Kurmuhchay, Kishchay, Shinchay, Mukhahchay, and Katexchay, etc. is characterized by strong dissection, abrupt steepness of slopes, and the presence of rocks which are easily given to destruction and denudation. Prevailing types of mud flows are alternating mud flow streams of structural and non-structural character. Considerable earth flows are observed every 2–3 years that remove more than 1 million m^3 of sediment. Their main inflow valleys are subject to the erosive influence of earth flows, as are pools with raised flows (Budagov and Alizade, 1988; Alizade, 2004).

On the Major Caucasus, the development of gravitation-denudation, including landslide and talus processes, the substantial influence of intensive modern neotectonic motions and active development at the present stage create disjunctive dispositions of which the basic are typically ecologically dangerous exodynamic processes. The widespread horst-synclinal plateau with abrupt slopes creates favorable conditions for the development of slide processes that strongly complicate the geodynamic situation on the Major Caucasus. Landslips, as well as flow centers, considerably reduce the area of mountain meadows and increase barren, strongly degraded, and potentially geodynamically dangerous sites. Large landslip-streams are typical of slopes on the horst-synclinal plateau, as at Afurdzja, Hyzy, Budug, Gyzylkaya, and Girdag, etc. Landslips are observed in areas with both damp and with rather arid-drought-prone climate, and they impose great harm on the economy of this region, for example, in pools of the river Katehchay, the left slope of the valley of the rivers Kurmukhchay, Kishchay, Shinchay, Mukhahchay, and Katexchay, etc. At the foot of the right slope of the river Kurmuhchay valley, there are landslips of rocks. The surface of the landslip is poorly inclined to the south. In its border zone from the east, north, and west, the uniform fault is well expressed on a relief surface. The landslide block threatens nearby settlements. Along the gravitation-neotectonic cracks crossing perpendicularly the most powerful radical rock landslips are consequently developed. On loosened slope deposits, especially in their bottom parts, secondary landslips are formed. In the high and middle elevations of the mountains, the rivers show widespread landslips consisting of materials from taluses and partial scatterings. On the left slope of the valley of the rivers Kurmuhchay and Kishchay, sudden landslips develop also in ancient alluvial and proluvial deposits.

Nival, high-mountain, and partly middle-mountain zones of development and exposures of rocks serve as arenas for collapses and mobile taluses, which actively participate in mud flow formation. They fall in areas of high slope relief, often collecting within the channels of water streams. Landslide and talus processes are frequent in the upper courses of the rivers Muhahchay, Kurmukhchay, Shinchay, Kishchay, Gusarchay, Velvelichay, and Gudialchay, etc. (Tarikhazer, 1997).

Proceeding from the above, it follows that natural-destructive phenomena such as avalanches, landslips, and collapses have deposited taluses, etc., and this defines the ecological intensity of the Major Caucasus. Activation of these processes, under conditions of amplifying anthropogenic influence, demands detailed research and regular generalization of these phenomena. Research into their occurrence and development will allow a characterization of the future course of their development. Hence, the account of these circumstances also creates a basis for the concept of management by ecological risk.

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Quaternary development of the Vere River Valley and meander formation: Geomorphologic paradox

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Keywords: varved clay, conglomerate, terrace, basis of erosion, alluvial plain, antecedent valley

The river Vere is a small right tributary of the Kura River in the adjacent environs of Tbilisi. This region is interesting not only from the point of view of its geological and geomorphologic development history, but also for the peculiarity of its natural phenomena, which took place during Quaternary time.

The stratigraphic subdivision of Quaternary deposits in the region is based on correlations of its continental formations with brackish-water deposits of Caspian area. In particular, according to the generally accepted stratigraphic scheme, there are the Bakinian, Khazarian, Khvalynian, and Neocaspian stages (Fedorov, 1960).Taking into account the lowering tendency of the Quaternary system boundary, the lower part of the boundary-line in the Ponto-Caspian area is drawn below the Quaternary deposits. According to it, in the chronostratigraphic scale of Quaternary deposits, the system in question is subdivided into the Eopleistocene (which includes the Absheronian, lower, middle and upper Pleistocene) and the Holocene-contemporary deposits. Though these subdivisions aren't correlated with terrace deposits in Tbilisi's adjacent environs, we base the sequence on our personal data.

According to the opinion of some authors, the Late Pleistocene "lake-sea" extended to the west across the valleys of the Caspian plain paleorivers and reached the environs of Tbilisi. From the argillaceous deposits of the "sea" bay, fauna were collected that dated the host rocks as Akchagylian (Alpaidze, 1967, 1969). To the northwest, these marine sediments are laterally replaced by coastal-continental sandstones. Further to the west, hypsometrically and stratigraphically above them, lie developed conglomerates, 150 meters in thickness, which construct the plateau-like Samgori upland and also the surface of Kashveti-Tsinubani mountain. Here, their thickness is about 30–40 meters. These uplands with conglomerates at present represent separated by the river Lochini valley relicts of ancient alluvial plain, developed near the Kura river mouth. Stratigraphically, these deposits correspond to the Akchagylian and Absheronian stages. Recently, Kashveti-Tsinubani conglomerates have been dated on the geological maps as Absheronian, i.e., as Eopleistocene.

During following period, the Kura River shifted to the southwest, antecedently working out through the valley relative to uplifted folded structures of the eastern wedge of the Trialeti range. As a result, in the environs of Tbilisi, the Kura River formed several terraces of post-Absheronian age. Analyzing the data of different authors, it is clear that there are differences in the determination of the number and structure of the terraces, their position in the valley, and indications of the absolute and relative heights of the terraces. The present authors hold the opinion of A.I. Janelidze (1925) about the presence of four cyclic terraces and accept their names based on results of the study of morphology and morphometry of all four terraces and their correlation with the stratigraphic scheme of the Caspian area (Alpaidze, 1972).

The river drainage system of Tbilisi's adjacent environs can be understood through preserved terraces in the valleys of the Kura River and its tributaries. In general, during the creation of the fourth Makhata terrace (Bakinian in age), the river drainage system of the region was already formed. During the process of general uplift of the territory and the penetration by the Kura River through valley, a consecutive system of sublatitudinal direction was developing on its right side. As for the left tributaries of the Kura River, in contrast to the right ones, they do not coincide with the srikes of fold structures and cross-cut them.

Not considering following development stages of the river drainage system and relief of the region, special attention should be paid to interesting geological-geomorphologic events related to the development history of the Vere River valley. In spite of low average annual outlay, this is 0.97m^3/sec., the latter three times exceeds the Digmis-tskali River, which is the second largest right tributary of the Kura River. This fact is explained by the high hypsometric position of the Vere River basin.

During the Quaternary period, the Vere River underwent an evolution related to three folded structures (the Lisi anticline, the Saburtalo syncline, and the Mamadaviti anticline) which changed the riverbed position and adjusted to their lithology and structure.

In the development process of the Vere River valley draws attention the appearance of gently dipping varved clays among the dislocated Paleogene bedrock, and the formation of incised meanders in the conglomerates, which unconformably overlie the bedrock in the modern riverbed.

Widespread in urban districts Vake and Saburtalo, bluish-yellowish varved clays were described for the first time by A.I. Janelidze (1927), who noticed that they were deposited in a lake formed in the Vere River valley as a result of damming of the river. Investigation of natural outcrops of varved clays shows that they are everywhere limited by rocky bedrock. According to their distribution, the depositional mode is clear: the clays were deposited in prolonged-winding depression linked to the Vere River valley. At the same time, neither the base of the varved clays nor their full thickness have been determined in their outcrops. Based on drilling data in one place, the base of the clays lies below the modern riverbed of the Vere River, and in another place, it is below the level of the Kura riverbed. These data cannot serve as an argument for denial of the lake formation, especially for its existence hypsometrically below the local erosion basis. This proposal contradicts the laws of river erosion.

The formation of meanders in the Vere riverbed is easily explained by the lithology of the rocks. But in the given case, meanders flow across a 15–20 meter thick suite of conglomerates, which unconformably overlie the eroded surface of the bedrock. The study of the cross section along the Vere River valley from its mouth to the exposure of its meanders shows that varved clays in the lower flow of the valley occupy the entire height of the outcrops, and only the surface is covered by a thin alluvium layer (1.5–2.0 m). In vertical section, the clays are replaced by sands and pebble-beds, which gradually occupy lower horizons and then the entire height of the section. This height along the total length of the cross section is determined by the height of the bulkhead that dams the river. After the lake filled with sediments, Vere River began meandering; due to damming, its erosion base was raised several tens of meters. This caused a decrease in the river gradient and reduced flow, which in the end became the reason for the meandering. Usually, the bulkhead of the dam (lake) is rapidly broken and the river also flows rapidly in the riverbed of the meanders, creating an uncommon situation for a mountain river with incised meanders. This is the geomorphologic paradox of the Vere River, which underwent a distinctive development history.

Acknowledgments

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The relationship between sea-level changes and tectonics in the southern Black Sea coasts of Turkey

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Keywords: neotectonic, uplift, morphotectonic, marine terrace, coastal landforms, coastal deposits

Introduction

The Black Sea is an important and remarkable inland sea that has been the subject of study by many native and foreign scientists. The Turkish Black Sea shore begins at the mouth of the Rezve River and extends to the border with Georgia, for approximately 1400 kilometers (Kos'yan and Magoon, 1993).

The Black Sea lost its connection with the World Ocean from time to time, at which times it was converted to an isolated lake. In this state, the sea had an independent water balance. Today, the Black Sea is no longer a lake environment but instead a marine environment with ocean connections via the Istanbul Strait and the Dardanelles. The collision of the Eurasian and Arabian Plates had begun the neotectonic evolution of Turkey, and the Black Sea coastal region formed a sub-neotectonic section (Şengör, 1980).

The other factor affecting the southern Black Sea region is the existence of neotectonic activity. In this study, some locations have been examined in the western, middle, and eastern parts of the Turkish Black Sea coastal region to understand the relationship between the coastal landforms revealing sea-level change marks and the tectonics of the coastal region.

Materials and Methods

This study is based on terrestrial observations. Pre-examination of the land was made using aerial photo examination. The landforms were photographed in the field. The stratigraphic sections of the marine terraces were drawn.

Measurements of the coastal deposits and terraces were made by tape measure, and elevations of the marine terraces were determined by GPS. Using these examinations and observations, the relationship between sea-level changes and tectonics in the southern Black Sea coastal region of Turkey will be explained.

Results

In the southern Black Sea coastal region, new marine terraces have been identified. These terraces were separated into three sections. In the west, the elevations of the terraces are 8 meters, 10–15 meters, and 17–18 meters. These are inclined towards the northeast. In the aerial photo observations, a west-east directed lineament (probable fault) has been identified behind the terrace.

In addition, the existence of hanging valleys and ruptures, asymmetric valleys, short and "V" shaped streams, and inclined river terrace all indicate a tectonic-controlled morphology. In the central Black Sea coasts, marine terraces were found at 52 and 32 meters in elevation.

At the same time, there exists an uplifted abrasion platform that is 4–5 meters in elevation, some of which is tilted with notches that are 5 meters high.

A marine terrace that is about 4–5 meters indicates that the coastal region has been uplifted. In the eastern Black Sea coasts, coastal deposits identified as marine terraces were described at 4, 6, 7, 12, and 22 meters. Some dislocations are considered at the terrace layers. Asymmetric river valleys and hanging valleys verify that the coastal region was uplifted by structural forces.

Conclusions

That the elevations of the terraces are different, very close to each other and display increasing elevations from west to east demonstrates the effect of tectonic activities in the coastal region. The situation of the marine terraces, their levels, and geomorphological anomalies prove that.

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Southeast Caucasus and its ties with Mediterranean countries in antiquity

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Archaeological evidence shows that the tribes inhabiting southeastern Caucasus have maintained diverse contacts with the world around them since antiquity. The ties were especially close with the cultural centers of the Ancient Orient but also with Mediterranean countries beginning in the middle of the first millennium BC.

The whole territory of southern Caucasus, including that of today's Azerbaijan Republic, was part of the Achaemenid Empire in the middle of the first millennium BC—as the Greek historian Herodotus, widely referred to as the Father of History, wrote in the 5th century BC (Histories III, 92, 97). This report has been confirmed by numerous archaeological artifacts, including remnants of the palatial buildings found during the excavations in Saritepe (Azerbaijan), Gumbati (eastern Georgia), and Benjamin (today's Armenia), as well as—and especially so—by our excavations in the vicinity of the village of Garajamirli in Azerbaijan's Shamkir Province over the past few years. The remains of the buildings are remarkable for their substantial dimensions and were found over an immense territory in Garajamirli. Among them, there is a seemingly palatial building that had a propylaea (an entry building) (510 m^2), a great courtyard with a park, and the main building that had a portico with 12 columns in two rows, an audience hall with many columns (675 m^2), other halls with colonnades, long corridors, and other premises. The total area of the complex approximates 20 hectares.

The Achaemenid Empire covered the vast territory from northwestern Africa (including Egypt) in the west to India in the east; from the Indian Ocean and the Gulf in the south to the Greater Caucasus in the north. The independent Azeri state—the Caucasian Albania with its capital city of Gabala—was established in southeastern Caucasus after the Achaemenid Empire collapsed under the armies of Alexander the Great in 330 BC. The southeastern Caucasus where the Albanian State emerged in the 4th century BC had maintained close contacts with the Mediterranean states, including Egypt and Greece, since the 6th century BC. Contacts with various Hellenistic states expanded yet further after the demise of the Achaemenid Empire. Trade expanded, and Albania was involved in it.

The Great Silk Road emerged in the same period; several branches of it crossed the territory of Albania.

The Greek author of the 2nd century AD, Claudius Ptolemaeus, mentioned 29 towns and other major populated localities in Albania (Geography, V, II, 29). The presence of so many towns in Albania as well as the richness of the country's natural resources promoted various applied crafts and expanded the country's trade relations. Numerous imported goods testify to those trade relations. Coins were used widely in the trade here beginning in the 4th century BC, as can be seen from the great coin hoards and the numerous individual coins found around Azerbaijan. The silver coins of Alexander the Great are so far the most ancient coins that were found in Azerbaijan. Local silver coins began to be minted in Albania—with the imitation of Alexander the Great's coins at first—not later than the beginning of the 3rd century BC. In addition, coins of the Seleucid Empire, the Greco-Bactrian Kingdom, the Parthian Empire, Egypt, Ancient Rome, and the other countries were in circulation there, too.

International relations influenced all facets of the local population's life, including the spiritual one, their culture, and city planning, as is clear from the numerous archaeological materials found all over the territory of Azerbaijan.

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Baery knolls – a key to the Caspian Sea history in the Late Neopleistocene

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Keywords: Northern Caspian Plain, bottom accumulative forms, morphology, lithology, lamination, "sheet" stream.

Introduction

Interesting forms of a relief, the so-called Baery knolls (BK), are wide spread in the Northern Caspian Plain. K. Baer was the first who paid attention to them. Subsequently, many articles have been devoted to these forms and some hypotheses relating to their genesis have been proposed: aeolian, erosion-accumulative, and coastal genesis. In Northern Caspian Plain, BK are present in the form of separate hills or ridges across wide terrains, but their relief is not within the Volga delta, but in the adjacent regions, surrounding the Volga mouth.. Their morphology and lithology are quite different compared with the surrounding relief.

Morphology, position

In the western part of the Northern Caspian Plain the coastline of the maximum stage of the Late Khvalynian Sea crosses the landscape at 0–3 m asl. From these elevations, the character of the relief on the plain changes. In the beginning there are extremely flat, low, extended positive forms with a height of about one meter, a width of ten meters, and a length of about hundred meters. They gradually become higher to the southeast, transforming into the shape of the typical BK and reaching heights of 10–12 m, for instance near settlement of Kharabaly (Fig. 1). There are many BK here; they look like the large waves and ridges but not of eolian origin (Badyukova, 2005a).

Figure 1. Baery knolls near the settlement of Kharabaly

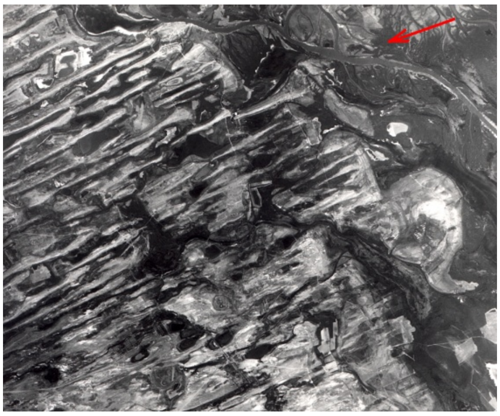

Figure 2. Long ridges seen from the air in the Volga delta.

To the south, the range of BK elevations reaches 8–10 m, and the hills have a general southwest orientation. These landforms are the same BK as those developed along the Volga delta (Badyukova 2000). The Novocaspian transgression did not reach this elevation, as a result, the BK were not destroyed. So the real relief of BK can be observed in this area, and not in the Volga delta or adjacent areas. In contrast, the BK within the Volga delta are prominently displayed because of swamp development in the depressions between the hills and ridges (so-called ilmeny) during the Novocaspian transgression and in contemporary times due to floods in the delta. Wind and abrasion of the ilmeny coasts apparently led to an extending of the depressions, which were draw out along the same direction. Moreover, sand from the ilmeny coasts created aeolian forms between BK, so separate hills appear to be the long ridges (Fig. 2).

Character of the deposits

The deposits composing BK consist of alternations of clay, silt, and sand. They are not uniform in structure, typically consisting of two large members – top and bottom. The whole series are represented by reddish-brown sandy-clayey sediments, which exhibit alternation of clay-sand or sandy layers with chocolate clay material – in pieces as large as 0.2 to 2 mm.

The lower member occurs, as a rule, on the chocolate clays, which often represent the basement. It therefore has more of a brown color. This basal horizon contains a rich complex of brackish water ostracods. It is composed of a thick layer of sand with chocolate clay pellets and abundant shell detritus, brackish and freshwater ostracods, and it also contains fragments and whole shells of mollusks of Khvalynian age (Q_3 hv_1 – Q_3 hv_2). The upper deposits contain more sand, fragments and whole shells of mollusks, brackish and freshwater ostracods, too.

In general we can speak of homogeneity in the structure of BK in various areas, although sometimes in sections, separate layers may be missing or their thickness and texture may vary. However, these differences do not change the overall picture.

A detailed study of bedded structure of BK showed that it is typical of unidirectional flow, drawn by bed and suspended load. A very characteristic feature of fluvial deposits is also revealed—unidirectional cross-bedded lamination. On the western and southwestern parts of BK, the lamination change: there is a monotonous alternation of sub-parallel layers, with angles of 20°–30°. The steady accumulation of the deposits moving along the already formed body took place here. BK were dynamic forms, and during their formations, they could be eroded from one side, further erosion often altered the formation of new deposits or overlapped forms with different, usually more sandier, lithology (Fig. 3).

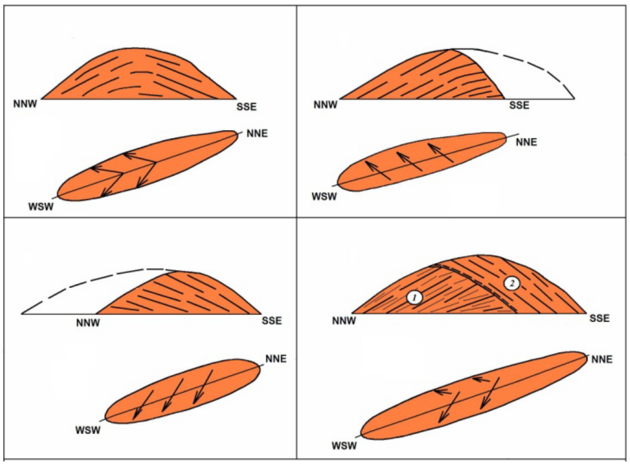

Figure 3. Variation in the deposition of BK

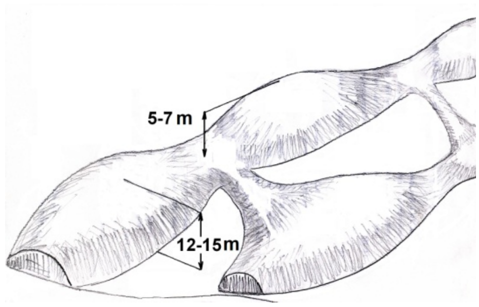

Figure 4. Morphology of the BK ridges

Baery knolls genesis

During Late Khvalynian time, stable currents dominated in aquatic environments (large lagoons). These currents have not been associated with a littoral zone with wave activity, as granulometric composition of the deposits, their sorting, and types of lamination are not typical of sediments from a coastal marine zone. They are characteristic of unidirectional currents with frequently changing velocities.

The formation of BK can be attributed to very wide "sheet" streams moving from NE to SW and further to Manych passage, which existed during the Late Khvalynian time (Badyukova, 2000, 2005b). One cannot exclude that, in the beginning, it was uniform, and that during the process of Caspian Sea level fall it became divided into a series of separate streams.

Baery Knolles are the analogues of river bedforms, which arise due to macro-scale turbulence of the flow. They are rather stable formations and their morphology strongly suggests this kind of explanation. Large bed and suspended load discharge are necessary for the formation of such river bedforms (Alekseevskiy, 1998).

Such river bedforms develop under processes of erosion, transport, and accumulation. The ridge forms are not the same for streams of different speed. In a quiet stream, a longitudinal profile of each ridge is often not regular. Morphology of the bottom forms and BK often reminds one of dunes (so-called bottom or river dunes) and “leeward” slopes of the BK are composed of steep layers with inclination at 25°–30°. Large ridges at the bottom have echelon location. The same locations have BK, i.e. their morphology is similar to the morphology of the bottom forms (Fig 4). Under experimental laboratory supervision, large sandy ridges were formed, and their formation has been estimated for a narrow speed range of 19–23 cm/c (Mel’nikova, 1997). The forms of ridges in the tray were various, and this can explain the diversity of BK.

In conclusion, the author believes that similar landforms are in other areas, for example, on Lake Chad and in the southern part of Western Siberia, where widespread hills (looking very much like BK) are aimed toward Turgay.

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Climatic and environmental changes in the Kuban delta (northeastern sector of the Black Sea coastal region) during the last 7.0 ka

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Introduction

Interdisciplinary archaeological-paleogeographical studies of the NE sector of the Black Sea coast were aimed at detailed reconstructions of paleoenvironmental changes in the Holocene under the influence of both global and regional factors. The reconstructions are based on comprehensive documentation of the coastal landforms and deposits, as well as on palynological characteristics of the principal sedimentary units in the delta plain parasequences.

Material and methods

The principal object of investigations was the sediments composing the Kuban delta plain and Bugaz spit. Lithologically, they are a transgressive-regressive sequence including peat and clay layers gradually replaced upwards with silts and sands. The latter are overlapped by sandy loams representing the uppermost member of the deltaic sediments. The sequence displays stages in the development of the outer part of the present-day Kuban River delta and variations in the deposition rate and lithology, which depend on fluctuations of the Black Sea level, as well as on the process of the delta front progradation and paleoliman infilling.

Detailed reconstructions of the changes in climate and environment along the Black Sea coasts of the Taman Peninsula over the period of the middle and late Holocene were based on materials from geological and geomorphological studies, lithological-facies and pollen analyses, as well as ^{14}C dating performed on liman-marine, alluvial, lacustrine, and subaerial deposits penetrated by boreholes in various parts of the Kuban River delta (Bolikhovskaya et al., 2004). The history of paleoclimatic events over the last 2500 years has not been adequately understood until recently. That may be attributed to insufficient geochronological data as well as to the incompleteness of the late Holocene sediment record. In recent years, however, new data have been obtained that shed light on the evolution of climate and environment at that time and clarify the chronological boundaries of some climatic phases (Bolikhovskaya et al., 2014).

Results

Pollen analysis and radiocarbon dating of samples from 6 boreholes (complementing each other) permit one to identify and characterize 14 phases in vegetation and climate evolution within the region over the last 7000 years.

At the end of the early Atlantic interval (6908–6640 cal BP), the territory under study was covered with herb and grass steppes (zonal type of vegetation), with isolated forest stands of hornbeam (*Carpinus betulus*) and oak (*Quercus robur*), with occasional admixtures of beech, lime, elm, poplar, alder, etc. The late Atlantic interval (~6000 up to 4500 cal BP) was marked by the prolonged dominance of forest-steppe landscapes under conditions of steadily increasing humidity. The forest formations of the automorphous landscapes were mostly those of *Carpinus betulus*, *C. caucasica*, *C. orientalis*, *Quercus robur*, *Q. petraea*, and *Fagus orientalis*, with some elm (*Ulmus laevis, U. suberosa*), chestnut (*Castanea* sp.), lime trees (*Tilia cordata, T. caucasica*), ash tree (*Fraxinus* sp.), maple (*Acer* sp.), hazel nut (*Corylus colurna*), hop hornbeam (*Ostrya* sp.), and other broadleaf trees. The open areas were occupied by steppes of herbs, grasses, Chenopodiaceae, and *Artemisia*.

In common with many regions of the East European Plain, the landscapes of the Taman Peninsula went through a series of changes. It should be noted that during the Subboreal and Subatlantic intervals, the changes occurred much more often than during the previous part of the Holocene. Twelve landscape transformations took place in the course of the last 4500 years that involve both zonal types (broadleaf forests, forest-steppes, and steppes) and some transitional types of landscape.

Seven climatic-phytocoenotic phases have been recorded in the Subboreal period. The first maximum of humidity (~4500–4300 cal BP) was marked by the prevalence of broadleaf forests, mostly with beech-oak-hornbeam and oak-beech-elm-hornbeam communities. Mixed coniferous-broadleaf forest stands, alder and willow groves were also quite common. Later on, during the phase dated at ~4300–4100 cal BP, the forest areas were reduced, and some landscapes of transitional type (from forest to forest-steppe) appeared. The assortment of edificators in the dominant plant communities, however, did not change noticeably. The forest reduction reached its maximum in the next phase, marked by almost total, though rather short-termed (~4100–3950 cal BP), dominance of steppe landscapes. The plant communities dominant in the steppe and littoral vegetation on the peninsula consisted mostly of grasses, grasses and herbs, and *Artemisia* and Chenopodiaceae (in varying proportions). Intrazonal forests in the lower reaches of the Kuban River included, along with alder and willow, stands of oak, hornbeam, and elm. The second maximum of humidity and, possibly, cooling (~3950–3500 cal BP) fostered the recovery of forest ecotopes. Automorphous landscapes of that time were dominated by oak-beech-hornbeam and beech-hornbeam-oak (with admixtures of elm, lime, and ash tree) formations, as well as coniferous-broadleaf ones.

Since then, the forest landscapes have never acquired the significance of a zonal vegetation type on the Taman Peninsula. From the mid-Subboreal period (~3500 cal BP), all the changes in vegetation amounted to transitions from steppe to forest-steppe and back.

The next phase in the vegetation evolution dated at ~3500–3200 cal BP corresponded to a new and considerable increase in the significance of steppe landscape. It has been noted for the dominance of grass, *Artemisia*-Chenopodiaceae, and herb-grass communities. The next interval (~3200–2800 cal BP) featured forest-steppe landscapes dominated by herb-grass communities in the steppe and meadow-steppe vegetation. Edificators in the beech-hornbeam-oak forests (rather limited in area) of automorphous landscapes were oak (*Quercus robur*) and Caucasian hornbeam (*Carpinus caucasica*). Both phases of the landscape evolution within the interval of ~2800–2300 cal BP—the steppe phase and transitional one from steppe to forest-steppe—were similar to the previous phases in the floristic composition of forest-forming species and steppe communities. Steppes were dominated by herb-grass and *Artemisia*-Chenopodiaceae communities. The ecotopes most favorable for arboreal vegetation—both within watersheds and along the coastline, as well as in the Pre-Kuban valley—were covered with forests of oak (*Quercus robur, Q. petraea*), hornbeam (*Carpinus betulus, C. orientalis*), beech (*Fagus orientalis*), elm (*Ulmus carpinifolia*), ash tree (*Fraxinus* sp.), lime tree (*Tilia cordata*), and others. Communities of beech, hornbeam, and oak were dominant.

Four phases have been distinguished in the climate and vegetation evolution of the Subatlantic period. The last considerable increase in climatic humidity marked by a transitional vegetation type (from forest to forest-steppe) and dated at ~2300–1650 cal BP is most probably correlatable with the Nymphaean transgression of the Black Sea. At the moisture supply maximum (most probably corresponding to the maximum of the transgression), forests of beech, hornbeam, and oak (*Carpinus betulus, C. caucasica, C. orientalis, Quercus robur, Q. petraea, Q. pubescens, Fagus orientalis*) were dominant in the region, with some elm, ash, hazel (*Corylus colurna*), and alder (*Alnus glutinosa, A. incana*). Between ~1650 and 1300 BP, the region was dominated by steppes of herbs and grasses and those of *Artemisia* and Chenopodiaceae, while forest ecotopes were drastically reduced in area. Groves of alder (*Alnus glutinosa, A. incana*) and willows occurred along streams and around freshwater lakes. Forest stands of hornbeam and oak (with some elm trees) were found occasionally in ecotopes suitable for broadleaf forests.

At the next forest-steppe phase (~1300–1000 cal BP) marked by some increase in climatic humidity, most forest communities (both in the lower Kuban valley and on flattened watersheds) were dominated by beech-hornbeam-oak formations. The last phase identified in the Subatlantic period

(~1000–900/800 cal BP) was noted for the most pronounced increase in aridity over the entire period of the Holocene under study. The sharp warming and decrease in humidity resulted in an almost complete disappearance of the forest ecotopes and a dominance of steppes (with herb and Artemisia-Chenopodiaceae communities).

Conclusions

The studies performed resulted in the first scheme of climate and environment dynamics on the Black Sea coasts of the Taman Peninsula; the scheme reveals the general trends in climatic evolution against the background of noticeable changes in the local environments, and topographic changes in particular, due to sea-level fluctuations.

Steppe and forest-steppe environments prevailed in the southern half of the Taman Peninsula, and probably in the lower reaches of the Kuban River, over the greater part of the studied interval of the Holocene (from ~7000 to 800 BP). Most of the warm and dry climate was reconstructed during several phases marked by the dominance of herb, herb-grass, and *Artemisia*-Chenopodiaceae plant communities; they are dated to 4100–3950, 3500–3300/3200, 2800–2400, 1650–1300, and 1000–900/800 BP. The maximum moisture supply within the considered period fell within the intervals 4500–4300 and 3950–3500 BP and notably, broadleaf forests (mostly of beech, oak, and hornbeam) spread widely within the region.

The changeability of climate, as well as that of the phytocoenotic successions grew essentially (almost three times) over the last 4500 years. The late Atlantic sub-period of the Holocene (6000–4500 BP) featured a prevalence of forest-steppe most of the time, while during the following ~4000 years, zonal and transitional types of vegetation—broadleaf forests, forest-steppes, and steppes—replaced each other more than 10 times. Herb-grass and *Artemisia*-Chenopodiaceae steppes were dominant on the Taman Peninsula before 2500 and after 1500 BP; between the cited dates, however, the dominance of steppe vegetation was repeatedly interrupted by more humid climatic phases, which resulted first in an increase in forest-steppe areas and later in a wide distribution of broadleaf forests in the forest-steppe landscapes dominant at that time.

Acknowledgments

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Holocene paleoenvironmental changes in the NW Black Sea based on ostracod assemblages

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Keywords: microfauna, mollusk fauna, sea-level rise

The Black Sea is a semi-enclosed marginal basin that connects with the Mediterranean Sea through the Bosphorus Strait, Marmara Sea, and Dardanelles Strait. In Late Pliocene-Pleistocene times, besides the connection with the Mediterranean Sea, the Black Sea experienced a period of connection with the Caspian Sea through the Manych Corridor due to the influx of meltwaters from the Scandinavian ice sheets (Fedorov, 1977; Chepalyga et al., 2004; Bahr et al., 2006; Major et al., 2006).

During Holocene times, the Black Sea basin underwent a major shift from a freshwater environment to a brackish one, which is mirrored in the biotic turnover. In the deeper parts of the Black Sea basin, i.e., below 200 m in water depth, Ross and Degens (1974) recorded three litho-stratigraphic units (from young to old): Unit 1 (the microlaminated coccolith ooze, deposited under marine conditions), Unit 2 (the sapropel mud, corresponding to a brackish, anoxic phase), and Unit 3 (the lacustrine lutite deposited during the freshwater or oligohaline stage).

This study is focused on the fluctuations in composition and abundance of the ostracod assemblages encountered in two undisturbed cores collected by multi-corer sampling. The cores were collected from the Romanian Black Sea shelf area, one from a water depth of 17.80 m in front of the Sulina branch and one from a water depth of 78 m in front of the St. George branch of the Danube Delta.

In the shallow water core, i.e. from 17.80 m water depth, the ostracod assemblages are influenced by the relatively high-energy environment linked to the Danube mouth. This feature is reflected in the conservation of ostracod shells, most of them being broken. Possibly, these taxa are, at least partially, transported.

In the deeper water core, the ostracod abundance and diversity indicate, during the Late Holocene, a sea-level rise from around 25 m to the current 78 m water depth. This sea-level rise is also supported by the shift in mollusk fauna, from the exclusive presence of *Mytilus galloprovincialis*, which inhabits the 20–25 m bathymetric interval, to its full replacement by the bivalve *Modiolus phaseolinus*, which prefers deeper environments (Briceag and Ion, 2013).

The ostracods from this assemblage tolerate salinities ranging between 17 and 21‰ and characterize a sub-littoral environment. Fluctuation in ostracod assemblages, based on qualitative and quantitative studies, are presented herein, together with a paleoenvironmental characterization.

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At the doorstep of the Pontocaspian and Mediterranean: Quaternary mollusk faunas from the Marmara Gateway

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Introduction

Episodes of isolation and connection between the Pontocaspian lakes of the Caspian and Black Sea basins and the Mediterranean existed during the Quaternary. The doorstep between the Mediterranean and Pontocaspian systems has been located in the Marmara Sea region as is shown by its Quaternary mollusk faunas (İslamoğlu, 2002, 2009; İslamoğlu and Chepalyga, 1998; Taner, 1983 and references therein; Taviani et al., 2014).

Here, we review the Quaternary mollusk record of the Marmara Sea region in order to understand the nature of the connections and periods of isolation. By emphasizing periods of dominant Pontocaspian environments as well as marine Mediterranean terraces, we aim to document the dynamic character of the Marmara region as a doorstep between these two very different faunal systems.

Methodology

First, we review the Late Quaternary mollusk-bearing successions along the southern shores of the Izmit Bay area. A combined sedimentological and paleontological inventory shows the condition during, and slightly after, the MIS5e sea-level optimum corresponding to the Tyrrhenian stage in the Mediterranean and the Karangatian stage in the Black Sea basin.

Second, we review the Middle-Late Pleistocene mollusk faunas around the Marmara Sea basin and adjacent Black Sea coast. The faunas include:

- Marine terraces from the Dardanelles and western margin of the Marmara Sea
- The Middle Pleistocene Pontocaspian and Mediterranean succession at Gelibolu
- Late Pleistocene Neoeuxinian faunas from the Marmara Sea floor
- Late Pleistocene marine terraces at Yalova in the northeastern Marmara Sea
- Middle Pleistocene Pontocaspian succession at Lake Iznik (İslamoğlu, 2009)
- Middle and Late Pleistocene Pontocaspian faunas from the northern Bosporus outlet and Sakarya River prodelta region (Görür et al., 2001).

Results

The Yalova fauna contains approximately 14 species of gastropods (İslamoğlu et al., 2001) and 24 species of bivalves (İslamoğlu et al., 2001; Schneider et al., 2005). The fauna represent two settings with salinities intermediate between the full marine Tyrrhenian faunas of the Mediterranean and the slightly lower saline (euryhaline) Tyrrhenian faunas of the Black Sea basin. The marine faunas show the presence of Mediterranean species during and slightly after MIS5e. The marine terraces of the western Marmara Sea region and Dardanelles go back to late Middle Pleistocene high stands, and some marine species have been reported from the early Middle Pleistocene of Gelibolu, showing the intermittent presence of marine connections to the south during Quaternary sea level high stands.

Pontocaspian faunas include the early Middle Pleistocene Gelibolu fauna that contains 19 species, several of which are truly modern Black Sea Pontocaspian species, the Middle Pleistocene terrace succession of Lake Iznik with its *Didacna* faunas, new Middle Pleistocene faunas discovered in the northern outlet of the Bosporus on the Black Sea side, and Late Pleistocene (Neoeuxinian) faunas known from various localities within the Marmara Sea basin floor as well as from offshore cores in the adjacent Black Sea.

In the Marmara Sea core material, transitions were observed between Pontocaspian and Mediterranean faunal types. Faunas earlier reported by Taner (1983) from the Gelibolu section contain an admixture of Pontocaspian and Mediterranean elements.

Conclusions

The Marmara Sea formed the threshold between the Mediterranean and Pontocaspian systems during the latter half of the Quaternary. At times, the region formed the southwesternmost extension of the Pontocaspian system. At other intervals, it provided marine gateways between the Mediterranean and the Black Sea basin, as is shown, for example, by the Yalova sections. In other time intervals, the Marmara Sea basin was occupied by an isolated lake, and continuous terrestrial connections existed between Minor Asia and the Balkans.

The fossil record of the Marmara Sea region holds further unexplored faunas that may greatly improve our understanding of the role of this region as a threshold between Pontocaspian and Mediterranean biota. The Pontocaspian terrace succession at Iznik Lake also holds promise to provide insight into the development of Pontocaspian faunas of successive transgressions during the Middle Pleistocene.

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North Black Sea passageway for the first peopling of Europe: Discovery of Oldowan sites in the Dniester Valley and Crimea

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Keywords: Oldowan, East Europe, Early Pleistocene, interdisciplinary study, Jaramillo event, stepping stones into Europe

Introduction

In recent years, many of the oldest archaeological sites in southern and western Europe possessing Oldowan cultural remains, were discovered in Spain, Italy, France, Bulgaria (Kosarnika), Georgia (Dmanisi), and Dagestan (Ainikab, Mukhkay). The question arises over the origin and the first migrations of humans from Africa to Europe (Aquirre and Carbonell, 2001).

As the Mediterranean Sea was an impassable barrier for migration, the problem of a passage for the first humans into Europe appeared to be avoiding this water basin.

Previous studies proposed that the closest way across the Near East, Anatolia, and the Balkan peninsula lay south of the Black Sea. But this so-called Levantinian (Balkanean) passageway has not been confirmed by evidence of any Oldowan sites. In the Eastern Mediterranean, no Oldowan culture sites have been found. Only two Acheulean sites—'Ubeidiya and Gesher Benot Ya'akov—were found in Israel, and a very late Acheulean occupation was found at Yabroud I in Syria. So, few documented Oldowan sites, and no basis for hypothesizing that this was the way to Europe.

Fortunately, a solution to this problem came from the other side—the northern Black Sea coast. Discovery of Oldowan culture in the multilayered sites of Bayraki and Kretesti in the Dniester valley (Chepalyga et al., 2012a, b) north of the Black Sea allows the hypothesis of a new passage for the initial peopling of Europe that went north of the Black Sea (Chepalyga, 2013).

Material and methods

New discoveries of Oldowan pebble culture in the Dniester valley and in Crimea permit us to reconstruct a new migration route north of the Black Sea from Caucasus along the Taman peninsula and the southern Crimea coast to Europe. This new way, the North Black Sea Corridor (Chepalyga, 2013) is based on a chain of 17 Oldowan sites that seem to be like stepping stones into Europe, connecting the Asian Oldowan area with the European one.

The best studied sites with Oldowan culture tools were discovered and excavated by N.K. Anisyutkin and A.L. Chepalyga in 2010–2014 in the Lower Dniester valley near the town of Dubossary, Moldova (Dniester Republic). Five sites related to the VII (Kitskany) terrace (125 m asl) sediments were recovered.

Results

Bayraki site. The multilayered site of Bayraki was excavated in Bayraki gully near the town of Dubossary (N 47° 16' 27"; E 29° 11' 10"). The VII Dniester terrace sediment section is 10 m in thickness and is subdivided into 10 lithological layers representing alluvial (channel, lake, flood plain) and fossil soil facies with six cultural layers: two Acheulean (I-II) and four Oldowan (III-VI) were excavated in lithological layers V, VI, VII, and IX.

More than 1000 stone artifacts (Figs. 1a and b) made from chert, quartzite, and other hard stones were found in Bayraki, mainly in layer V.

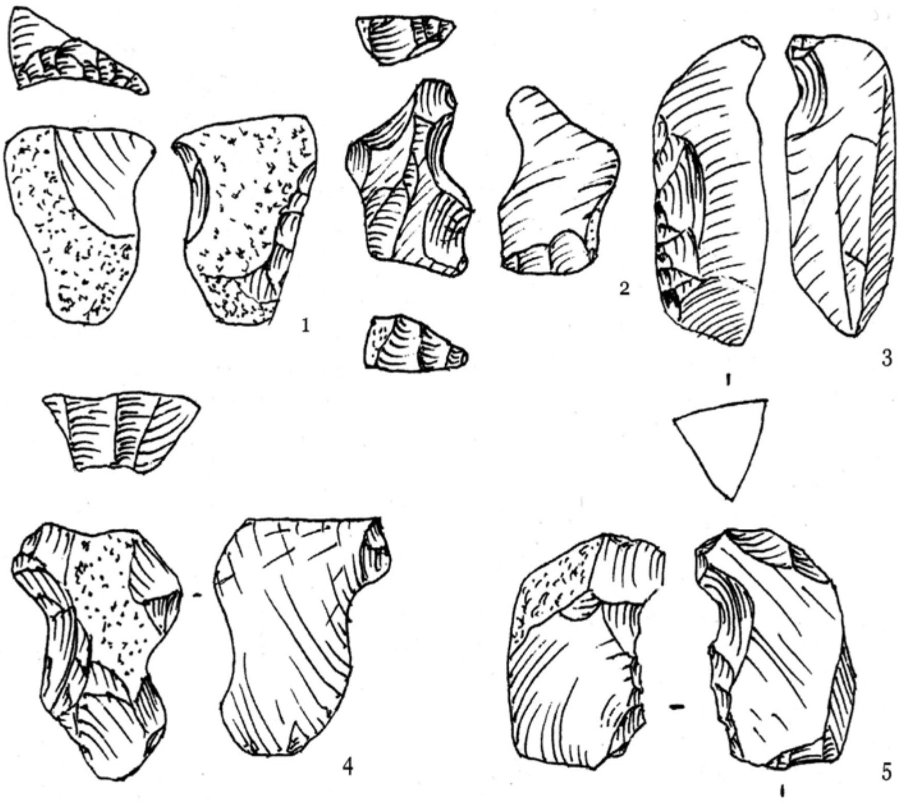

Figure 1. Bayraki tools from culture layer V (Oldowan). 1– 5 – bill hooks.

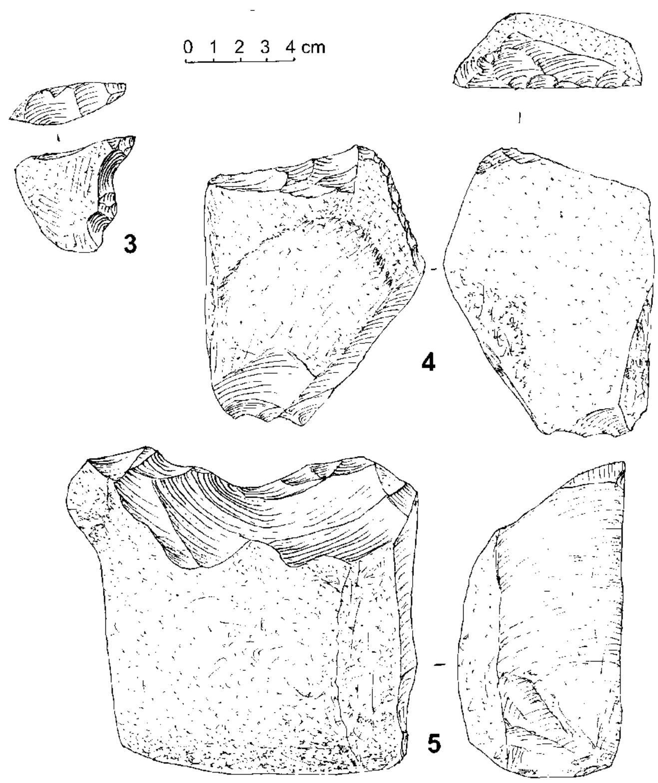

Figure 2. Bayraki tools from culture layer V (Oldowan). 3 – chert bill hook, 4 – bifacial chopping tool (sandstone), 5 – unifacial chopper (sandstone).

Several hundred tools belong to heavy duty, light duty, and microtools, including choppers, chopping tools, bill hooks, end- and side-scrapers, borers, rabots (scraping-planes), and protoknives. This stone industry belongs to the Developed Oldowan culture Mode 1. Some tools were heat treated. A stone pavement made from prepared limestone plates (up to 65 cm long), accompanied by tools (chopper, bill hooks, scrapers) were recovered in culture layer IV. Use of such a pavement construction is unknown; possibly it was a location for animal skin preparation (on the basis of the absence of bones, and presence of bill hooks and scrapers).

Mammalian remains of *Archidiskodon meridionalis tamanensis* and *Equus sussenbornensis* are typical for the Tamanean complex (= Epivillafranchian). The mollusk fauna contains freshwater bivalves of extinct genus *Pseudosturia (P. caudata)* and other extinct unionid species (*Crassiana crossoides*, etc.).

Age of the Bayraki cultural layers. Paleomagnetic studies recovered signs of the Matuyama and Brunhes chrons as well as the Jaramillo event 0.99–1.07 Ma. Oldowan cultural layers III–VI fall within the Jaramillo event, and layer VI continues below it. This suggests the age of the Oldowan Bayraki site lies within the frames of 0.95–1.1 Ma. Acheulean layers I–II appear at the base of the Brunhes paleomagnetic chron, somewhat younger than 0.78 Ma. This age is confirmed by paleontological data (= upper part of the early Pleistocene).

Paleomagnetic data are shown in Fig. 2

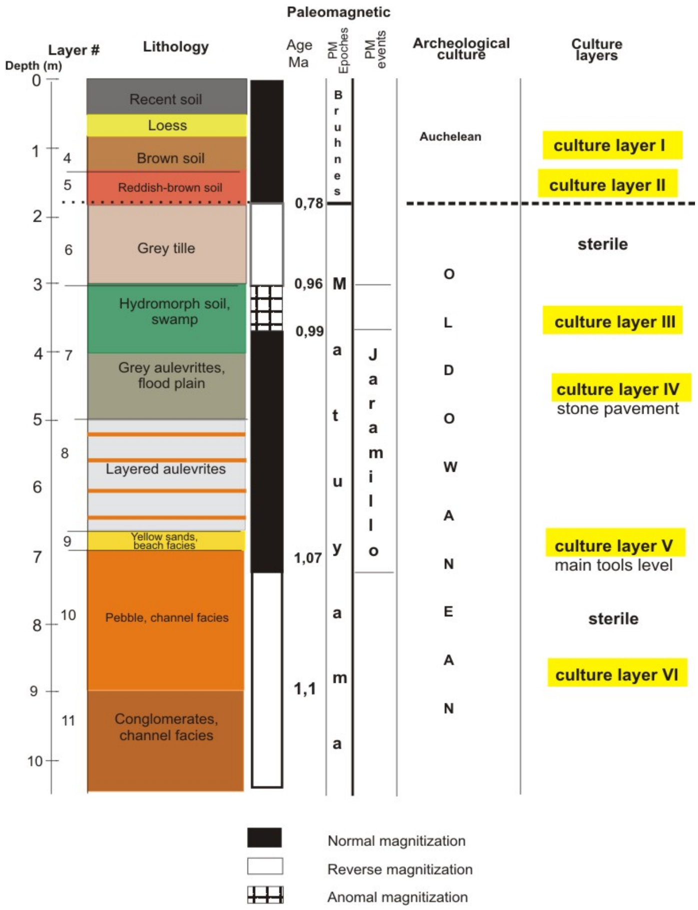

Figure 2. Bayraki multilayer site: sediments, paleomagnetic age, and archaeology (position of the culture layers).

Table 1. Lower Pleistocene Ponto-Caspian stratigraphy, isochrons, tectonic phases, and marine basins.

Stratigraphy regostages					Iso-chrons Ma	Paleo-magnetic scale: Epoch	Paleo-magnetic scale: Events	Sediments: River	Sediments: Marine		Tectonic phases	Archeo-logical cultures
ANTROPOCENE	NEOPLEISTOCENE	Upper	Khvalynian			BRUNHES		River valleys	Khvalynian		Stabilization	ACHEULEAN
			Atelian						Atelian			
		M	Khazarian						Khazarian			
		Lower	Bakinian						Bakinian		Passadenian phase Stabilization	
	LOWER PLEISTOCENE		Apsheronian	Upper	0,78* 0,80* 0,85* 0,97* 0,99* 1,07*	Matuyama	Kamika-tsura Yaramil-lo	Akusha formation: Upper	Apsheronian basin	Later	Valakhian phase Stabilization Marine transgression	OLDOWAN
				Low er	1,10*		Kobb Mauntaine	Lo wer		Earl y		
NEOGENE	PLIOCENE	Upper	Akchagylian	Upper	1,21* 1,24*		Olduvai				Uplift. Erosion. Stabilization Akchagylian marine transgression Rodanean phase	
				Lower	1,8* 2,0* 2,6	Gauss					Stabilization Deep regression Atticue phase	
		L	B a			Gilbert						
	MIOCENE	Upper	P o									
			Meotian		3,6 6,0	V epoch						

Southern Crimea localities

Between the Dniester valley in Europe and the Taman peninsula in Asia, Oldowan sites presented a gap, an interruption in the human occupation area for a distance of 800 km.

Fortunately, another group of Early Paleolithic, possibly Oldowan localities, was recovered on the southern Crimea coast (Schepinsky and Klukin, 1992; Zuk, 1995; Stepanchuk, 2006): Echki-Dag, Artek, Gaspra, Laspi, Blue Bay, Cap Majachny—a total of 6 localities.

These localities were not studied stratigraphically, not yet studied by geoarchaologists, and not yet dated. Some of these localities are represented by a set of sites, for example, Echki-Dag (20 localities). Some of them are in stratified sections and contain fine alluvial and lagoonal facies. These sediments are available for analytical studies (sedimentology, palynology, paleontology, paleomagnetism) and can be dated. In the region near Sudak town, some marine and proluvial terraces were studied, for example, the Tyrrhenian (Karangatian) terrace with a mollusk fauna including *Paphia senescens*.

Southern Crimea artifacts belong to a pebble tool assemblage, close to Oldowan, represented mainly by heavy duty (choppers, chopping tools, scrapers, protoknives, and protobifaces) as well as light duty microtools (Zuk, 1995).

South Crimean and Dniester valley localities provided a good base for the reconstruction of a passageway for the earliest human invasion of Europe prior to 1 million years ago. These findings can indicate the first steps of Oldowan people into the European continent after leaving the territory of the Taman peninsula, located in Asia.

Conclusions

Southern Crimea closes the gap between West Asian (Taman peninsula) and European (Dniester valley) Oldovan localities with the presence of many sites with artifacts.

Final conclusions at this moment can be made concerning the origin of a passageway. Reconstructed here in Fig. 3 is the North Black Sea Passageway (NBSP) for the first Oldowan migration from Asia (N. Caucasus) to the European continent. The line of this route completely coincides with the direction and frames of our IGCP Projects 521 and 610 involving the Caspian-Black Sea-Mediterranean Corridor.

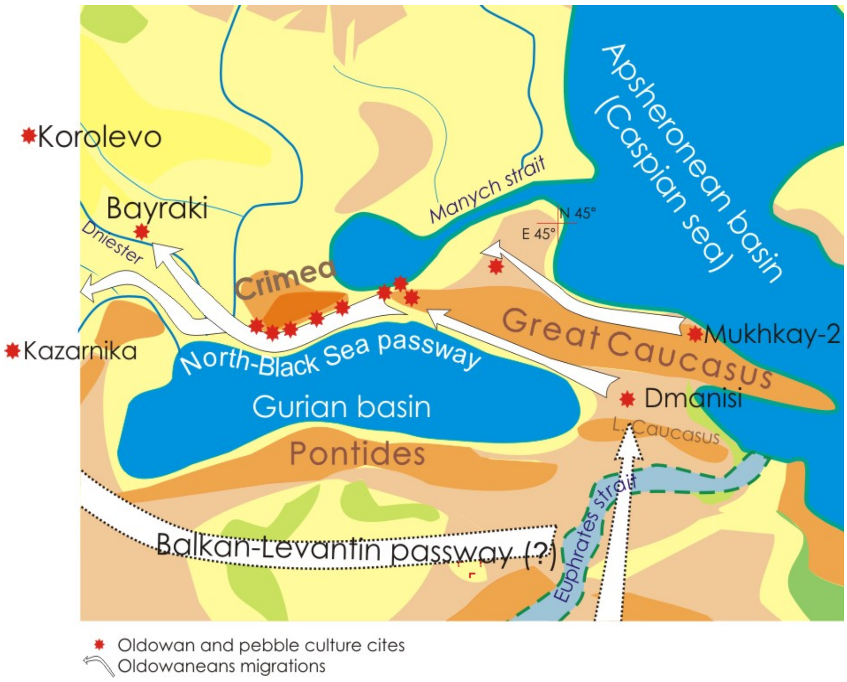

Figure 3. North Black Sea Oldowan Passageway during the Lower Pleistocene.

There seems to be a submeridionally-oriented channel for natural processes: water mass exchanges, marine fauna migrations, natural landscape border of the inner marine basin coastlines and human migrations along the NBSP. Possibly, the migrations were controlled by the abovementioned natural processes. We need to explain why the initial submeridional south-north direction of the first migrations (2.0–1.5 My) was changed and sharply turned to the west into Europe (1.5–1.0 My) and continued to the Atlantic (Atapuerca). The point of this turn coincides with the Manych strait and the

Azov-Kuban gulf as a water barrier. These facts are information for discussion about the influence of natural processes on human evolution.

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Coastal vulnerability at archaeological sites of the Taman and Kerch peninsulas

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Keywords: The Sea of Azov, Kerch strait, sea-level rise, coastal vulnerability, archaeological sites

Introduction

The Kerch and Taman peninsulas possess numerous archaeological sites, most of which belong to the Hellenistic period and are located within the modern coastal zone. Their peak period of occupation falls in the 1st century BC, during the Bosporan Kingdom with its capital at Panticapaeum (modern Kerch). It is significant to note that most ancient settlements of the Taman peninsula are partly submerged, whereas most ancient settlements on the Kerch peninsula are located above the modern sea level. Due to continuous World Ocean rise, the coasts of the Black Sea and Sea of Azov have been exposed to destructive geomorphologic processes. Coastal retreat reaches 6–8 meters per year in some places along the east of the Sea of Azov. Many sites both already excavated and not yet excavated are at risk within this coastal zone.

Methodology

We tried to estimate the consequences of sea-level rise and its impact on the archaeological sites in this study. We based our inquiry on the methodology for assessment of coastal vulnerability elaborated by P.A. Kaplin and A.O. Selivanov (MSU). This methodology combines both the natural vulnerability of coastal segments and the negative consequences of human impact. Therefore, the general integrated expression for vulnerability, A, within a coastal segment under a possibly accelerated sea-level rise takes the following form:

$$A = V\,\Sigma R_n, \qquad (1)$$

where V is the natural vulnerability index, and ΣR_n is the sum of all resource values R_n, including various kinds of natural, economic, and cultural resources. Based on this methodology, we divide the coasts of the Taman and Kerch peninsulas into four groups:

- extremely vulnerable;
- vulnerable;
- relatively stable;
- stable.

Results

Results of our study are shown in Figure 1. Here, we indicate four areas on the Kerch and Taman peninsulas according to the Kaplin-Selivanov classification. We took into account the sum of all factors influencing coastal vulnerability. The northern part of the Taman peninsula appears to be the most vulnerable system. Coastal abrasion here reaches values of 1–1.5 meters per year. Also vulnerable are the southern part of Taman Bay and the coasts of Kerch Strait southward from Kerch Bay and the small peninsulas (tombolos) on the northern coast of the Kerch peninsula, such as Cape Zuk. We identified coasts around Kerch Bay as relatively stable, as well as the northern part of the Kerch peninsula formed by an alternation of narrow bays and rocky limestone capes. The Bay of Kazantip was identified as a stable region due to its full profile beach and vast Holocene terrace.

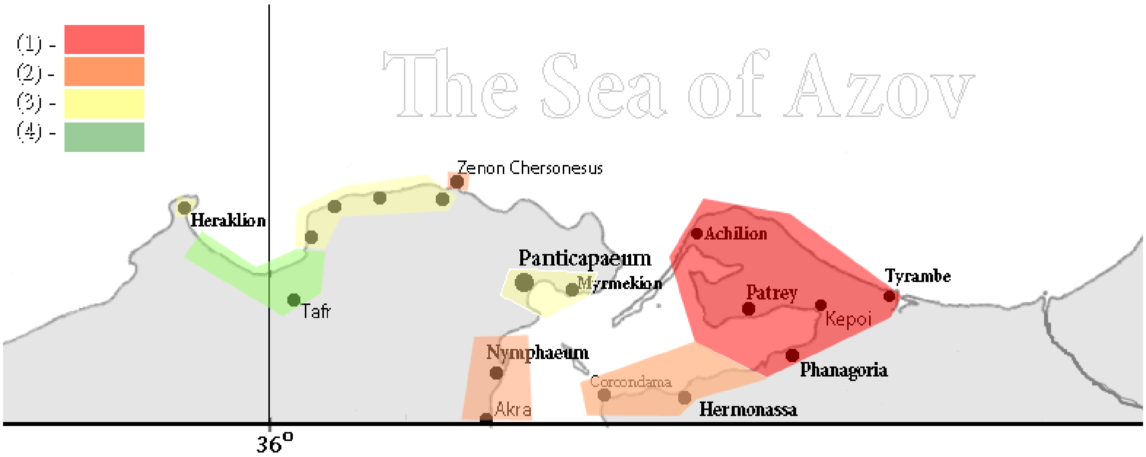

Figure 1. Schema showing coastal vulnerabilities on the Kerch and Taman peninsulas.

Conclusions

A substantial number of ancient settlements is located within the risk zone according to our investigation. Most vulnerable are Phanagoria and Patrey. Two thirds of their territory is submerged nowadays, and coastal destruction continues. Less vulnerable are sites on the other side of Kerch Strait: Nymphaeum, Acra, and Cytaea, located on the high cliffs. Relatively stable is the "Karalar" coast (north of Kerch peninsula), where settlements are located in small bays between prominent rocky capes. Stable are the large bays (like the Bay of Kazantip) and all settlements in such bays, as well as those that are far from the present shoreline.

Acknowledgments

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Experimental reconstruction of the Black Sea coast and shelf evolution during the Pleistocene

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Keywords: coastal abrasion process, mathematical modelling, Black Sea terraces

A mathematical model of the abrasion process during conditions of sea-level change was developed in the 60s and 80s of the last century (Esin et al., 1980). The model has been written as a system of two differential equations in total derivatives. The analysis showed that if the velocity of the sea-level rise does not change, then the asymptotic solution of the system (at $t \to \infty$) can be written as:

$$V_x = u \cdot ctg\alpha \qquad (1)$$

$$V_y = V_x\, tg\beta - u \qquad (2)$$

In equations 1 and 2, V_x and V_y represents velocities of cliff retreat and bench deepening, respectively, u represents the velocity of sea-level rise, α represents the angle of the seabed which was released from the zone of wave action, i.e. the angle of the formed shelf, and β represents the angle of the bottom slope at the intersection of the cliff and bench.

Equations (1) and (2) show that, under dynamic stabilization, the cliff and wave breaking zone move towards the land with the same constant velocity.

Excluding V_x from (1) and (2), we obtain:

$$tg\alpha = \frac{tg\beta}{1 + A}, \qquad (3)$$

where $A = \frac{V_u}{u}$ – abrasion number characterizing the intensity and degree of the cliff abrasion process under the wave action: the more A , the more gently sloping will be the shelf that is formed.

The velocity of the glacio-eustatic sea-level rise changes very slowly. Therefore, in a first approximation, we can assume that at each moment, the abrasion occurs under conditions close to the stage of dynamic equilibrium. Therefore, the formula (3) may be used for evaluating the formed shelf profile $y = y(x)$ for all times during the transgression. If we denote $tg\alpha = \frac{dy}{dx}$, then we obtain the differential equation:

$$\frac{dy}{dx} = \frac{u \cdot tg\beta}{u + V_y}, \qquad (4)$$

The function $u = u(t)$ should be presented as $u = w(y)$ to solve this equation. Then we obtain the equation:

$$\frac{dy}{dx} = \frac{u(y)tg\beta}{u(y) + V_y(y)} \qquad (5)$$

For Pleistocene transgressions, the slow increase in sea level at the beginning and at the end of a transgression is characteristic. At this time, the abrasion forms gentler parts of the coast and shelf as underwater or raised terraces. Therefore, in a first approximation, the course of sea-level change can be approximated by the function $y = L(1 - cos\omega t)$, where $\omega = \frac{2\pi}{T}$, T – period. Then we obtain the equation for calculating the profile of the coast and shelf:

$$\frac{dy}{dx} = \frac{\omega\sqrt{2Ly - y^2} \cdot tg\beta}{\omega\sqrt{2Ly - y^2} + V_y} \qquad (6)$$

The solution of equation (6) describes the profile of the coast and shelf:

$$x = \frac{1}{\omega}\pi ctg\beta + yctg\beta + \frac{1}{\omega}V_y\pi ctg\beta \arcsin\left(\frac{y}{L}\right) \qquad (7)$$

Where $V_y = const$ is the constant describing the degree of bottom destruction. It depends on the strength of the rock and the height of the waves.

The shelf profile formed during a transgression, with the scope of the level fluctuations equal to 126 m, is shown in Fig. 1.

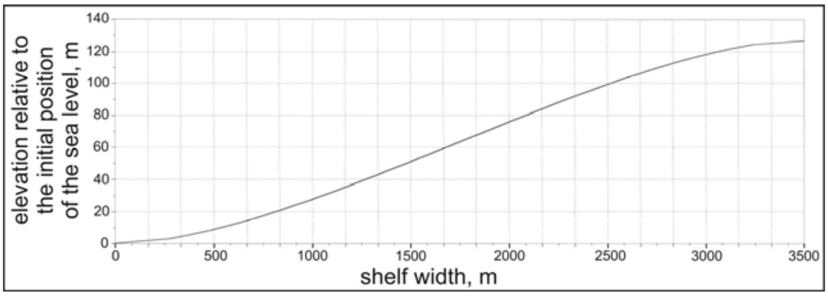

Figure 1. Example of the Caucasian shelf profile calculation after a transgression with scope of 126 m and transgression time 20 ky.

The recent coast and shelf of the Black Sea have been formed by many Pleistocene transgressions (as an example, Fig. 2).

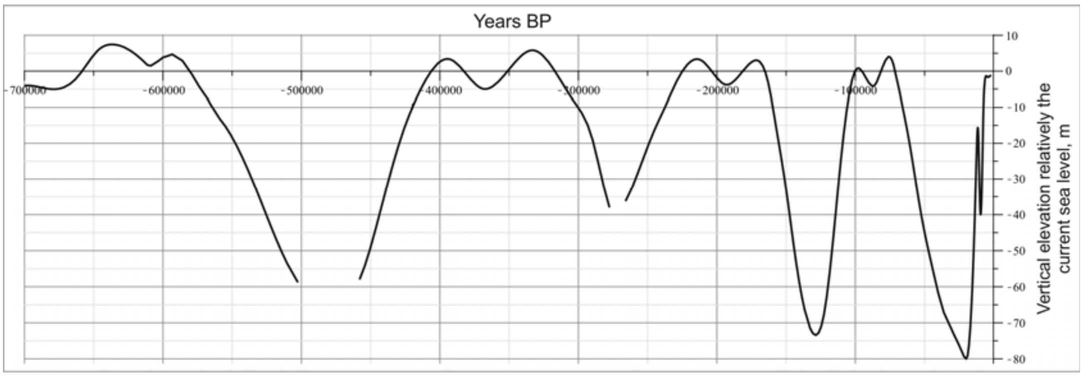

Figure 2. The curve of sea-level change in the Black Sea during the last 700,000 years proposed by P.V. Fedorov (1978). The last part of curve, from 20,000 BP till now, has being added by authors (Esin et al., 2010).

Therefore, the current profile of the shelf and coast bedrock can be obtained by superposing successive sections after each transgression, also taking into account the vertical movements of the earth's crust (Fig. 3).

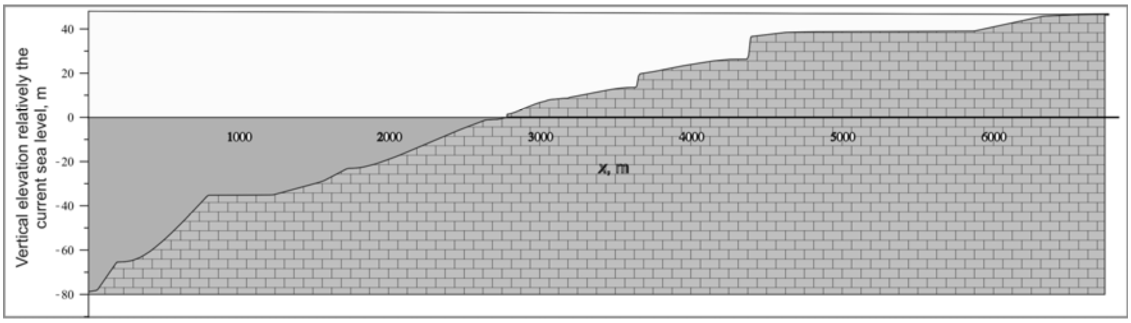

Figure 3. The calculated profile of the coast and shelf obtained using the curve of sea-level change indicated in Fig. 2.

Earlier (Esin et al., 1986), a reconstruction of the shelf evolution in the northeastern part of the Black Sea was performed by a simpler method. Studies have shown that the theoretical (calculated) profile of the shelf comes close to the real profile as obtained through the results of geophysical studies, if in the calculation we use several changes to the Fedorov curve, Using the described methodology, it should be possible to reconstruct the progress of the Black Sea and the evolution of different parts of the coast and shelf of the Black Sea during the Pleistocene.

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The Black Sea basin filling by Mediterranean saltwater in the Holocene

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Keywords: Bosphorus Strait, two layer flow, mathematical modelling

One of the most important natural processes that took place in the Black Sea during the Pleistocene was a recurrent salination and desalination of the sea water. Salination occurred when the World Ocean level was high after the formation of a bottom counterflow in the Bosphorus Strait. Desalination took place when the World Ocean level was low under conditions of unidirectional water flow from the Black Sea to the Mediterranean Sea. During such a period, salt together with water was carried out. In the present work, the mechanism of the Black Sea water salination is described. It began about 9500 years ago, according to modern interpretation of evidence.

A mathematical model of the quasi-steady two-layer flow in the Bosphorus Strait is considered in the article of Oguz et al. (1990); one for non-stationary flow appears in the paper by Ozsoy et al. (1998). In both models, the Boussinesq equations were used to describe the water circulation. We used the Navier-Stokes equations for the analysis of the two-layer flow development. In contrast to the Boussinesq equations, they describe water motion taking into consideration attrition between layers. In the future, this will permit calculation of the process of capturing counterflow water by the upper stream and its return to the Marmara Sea. Such a process is described in the paper by Jarosz et al. (2011).

Within the bottom counterflow, water runs under the influence of gravity, as denser liquid in less dense. From below, the layer of counterflow is bounded by the bottom surface, from above, it is bounded by a liquid layer that separates the stream from the counterflow. The current velocity of this liquid is equal to zero. Thus, water within the counterflow flows as if it was between two surfaces. In such a situation the Navier-Stokes equations give the following solution:

$$U_{dn} = \frac{g\Delta\rho}{2\rho_s\nu}\left(H_{dn}z - z^2\right)\sin\alpha; \tag{1}$$

$$Q_{dn} = \frac{g\Delta\rho l H_{dn}^3}{12\rho\nu}\sin\alpha. \tag{2}$$

Where U_{dn} represents water velocity in counterflow, g represents the acceleration of gravity, $\Delta\rho = \rho_s - \rho_{up}$, ρ_s equals the density of the Mediterranean water, ρ_{up} equals the density of the Black Sea water, H_{dn} represents the depth of the lower stream layer in the southern part of the strait, z represents a vertical axis, l is the width of the strait, α equals the average angle of the bottom slope, ν is the kinematic viscosity coefficient, and Q_{dn} represents water discharge in the counterflow.

The upper water stream flows due to the difference ΔH between the Black Sea and Marmara Sea levels. This can be written as

$$U_{up} = \frac{g}{2\nu}\frac{dH_{up}}{dx}z(2h - z); \tag{3}$$

$$Q_{up} = \frac{\left[H_{up}^4 - (H_{up} - \Delta H)^4\right]gl}{12\nu L}; \tag{4}$$

$$H_{up}^4 - (H_{up} - \Delta H)^4 + \frac{12\nu Q_{up}}{gl}(L - x). \tag{5}$$

Here H_{up} is the depth of the upper stream in the southern part of the strait, Q_{up} is the water discharge in the upper part of the strait, L is the length of the strait, and the x axis is directed along the plane of the flow.

In the case of quasi-steady flow, water discharge in the upper stream is equal to the counterflow discharge plus a value for the freshwater balance. This gives the following algebraic equation:

$$\frac{lg\Delta\rho H_{dn}^3 \sin\alpha}{3\rho\nu} + Q_{fresh} = \frac{[H_{up}^4-(H_{up}-\Delta H)^4]gl}{12\nu L}. \qquad (6)$$

The analysis of this ratio has shown that the Mediterranean counterflow breakthrough occurred when the depth of the strait was 16.5 m at about 9400 years BP. But earlier, during the period, when the Black Sea freshwater balance could be negative (during short periods of time, for example, some winter periods), small amounts of Marmara Sea water occasionally penetrated into the Black Sea.

In accordance with theoretical conclusions of the previously developed model, we consider that about 10,000 years ago, the strait depth was 10 m, the rate of strait bottom rise due to accumulation was 3 mm/yr, and during the period between 10–7 ky BP, the velocity of the Black Sea level rise was 13.5 mm/yr. Thus, the total depth of the strait during this period was growing with a velocity of 10.5 mm/yr. Such a consideration permits one to write the correlation (6), as follows:

$$\frac{lg\Delta\rho H_{dn}^3 \sin\alpha}{12\rho\nu} + Q_{fresh} = \frac{gl}{12\nu}[(16{,}5+0{,}0105\,t - H_{dn})^4 - (16{,}1+0{,}0105\,t - H_{dn})^4] \qquad (7)$$

When examining average values of water circulation of 0.3 m and 0.4 m, we get temporal dependencies between counterflow depth and volume of salt water inflowing into the Black Sea. A diagram of the Black Sea basin filling with Mediterranean water is given in Fig. 1. Calculation has shown that during the first thousand years, only 0.3 x 10^3 km^3 of salt entered the Black Sea (Fig. 2). Later at 8400 years BP, the average depth of the counterflow was 16 m, and water discharge within the counterflow was 700 km^3/yr. A rapid filling of the Black Sea with salt water has given birth to the hypothesis that water was overflowing along the strait as the upper stream. In fact, the bottom counterflow supplied the water.

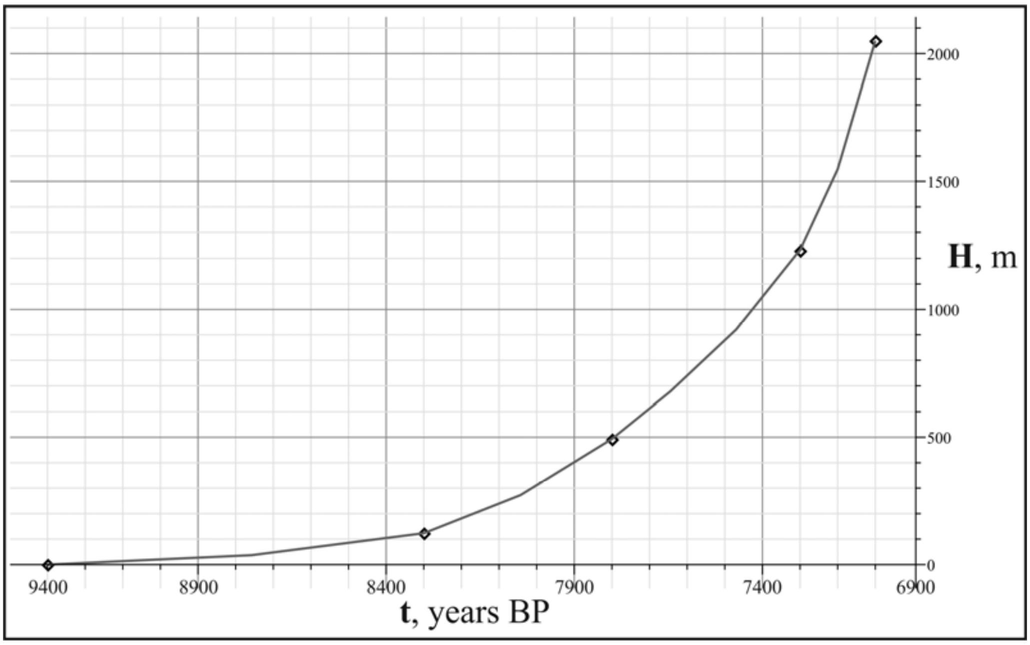

Figure 1. Graph of the Black Sea basin filling with Mediterranean salt water. Curve indicates an increasing of the halocline level.

At 7000 years BP, the average velocity of the Black Sea rise roughly decreased to 0.5 mm/yr, and the process of strait shallowing started. By now, the depth near the southern threshold had decreased from 45 to 36 m. Accordingly, water discharge in the counterflow became less, too.

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Black Sea basin infilling by suspension flows during the Quaternary

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Keywords: abyssal plain, lateral sedimentation, Newton liquid, Navier-Stokes equations, density, viscosity

Recent seismic survey reveals a lateral infilling of the Black Sea's deep basin by a thick, almost horizontal, acoustically parallel-stratified sedimentary sequence during the Cenozoic. The basin floor represents an abyssal plain at a water depth of about 2000 m. Inclination of the flat plain surface decreases from 5×10^{-2} at its periphery to 3×10^{-4} in the central part. The question arises, how the fine-grained terrigenous material of river discharge transported down-slope by gravity flows reached the basin center to contribute to the stratified infilling sequence accumulation, in the process traversing hundreds of kilometers over an almost horizontal plain. We describe here a possible mechanism for bottom suspension flows which may be responsible for the sediment transport over the abyssal plain under conditions of very slow bottom currents unable to produce contourites.

Sub-horizontal parallel-stratified seismic facies truncated from below against the basin slopes are commonly interpreted as turbidites. However, the DSDP site 379 drilled in the deepest central part of the abyssal plain, at a water depth of 2171 m, recovered a 624.5 m thick Quaternary section of alternating hemipelagic terrigenous mud, nannofossil ooze, and diatom ooze that contains only a few thin turbidite layers. Terrigenous mud with numerous turbidites is recovered only in the interval of 290–450 m below the sea floor (Ross et al., 1978). The upper part of the section was strongly disturbed by drilling, but nearby piston cores recovered thinly laminated (varved) Holocene sediments composed of alternating seasonal nanno ooze and terrigenous mud millimeter-scale laminae. The varve counting provided chronostratigraphy corresponding well to the regional stratigraphic scale (Ross and Degens, 1974). The authors note that turbidity currents may carry a substantial amount of detritus to the deep basin. During the last 1500 years, the varve section was interrupted five times by distal turbidites. Sharp boundaries between the individual laminae suggest a lateral near-bottom sediment transport at least for the individual terrigenous mud laminae instead of the vertical (e.g., pelletal) settling from the water column by the hemipelagic mechanism.

We believe that the terrigenous material may move on the abyssal plain as a gravity-forced suspension flow. The suspension consists of mud particles in the sea water, and it moves over the bottom as a heavy liquid owing to its density higher than that of surrounding sea water. This movement can be described by the Navier-Stokes equations.

Special experiments carried out on a suspension prepared by mixing sea water with the Black Sea deep-water mud (Esin, 2003) showed that a suspension with a density of 1.05 to 1.26–1.33 g/cm^3 behaves as a Newton liquid. In laminar flow, its viscosity coefficient ν gradually increases with increasing density. When the suspension density > 1.26 and < 1.32 g/cm^3 (for different samples), the ν values start to increase sharply. It indicates that the suspension liquid transits to the viscous-plastic condition (Bingam-Shvedov body) (Fig. 1).

Investigations in the framework of the project IAEA RER/2/003/ showed that the uppermost 10 cm thick sediment layer with a density of 1.05–1.3 g/cm^3 behaves not as a sediment, but can slowly flow as a suspension.

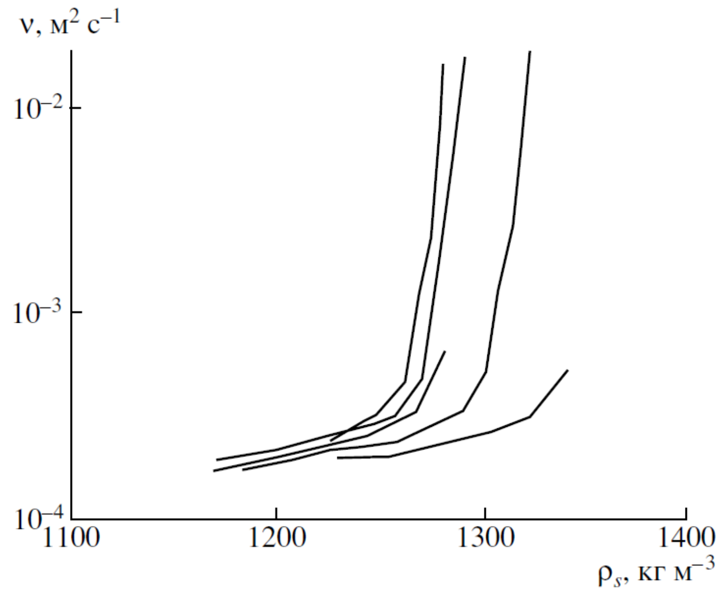

Figure 1. Dependence ν coefficient from density of suspension ρ_s for Black Sea sediment. The depth of the sea: 1300–2000 m.

Our laboratory experiments in a chute demonstrated that such a suspension flow behaves as a continuous viscous medium (not considering particles settling onto the sea bottom). The "continuity" means that each particle is surrounded by water moving together with it, thus representing the so-called linked mass. In the suspension, linked masses connect to each other forming a liquid heavier than the sea water.

The solution of the Navier-Stokes equation system in linear approximation to the gradually deepening abyssal plain (with angle α) is expressed by:

$$u = \frac{g\Delta\rho}{2\gamma\rho_s} cos\alpha \left(tg\alpha - \frac{dh}{dx} \right) z(2h - z) , \qquad (1)$$

where g represents acceleration of gravity; $\Delta\rho = \rho_s - \rho$, ρ_s and ρ represents densities of suspension and sea water, respectively; $\frac{dh}{dx}$ is the inclination of the free suspension flow surface relative to the horizon; u represents the suspension flow velocity; and z is the vertical ordinate (perpendicular to the bottom). For h we obtain the equation:

$$12Q\nu\rho_s \ldots 1, \qquad (2)$$

where h_0 is the thickness of the suspension layer in the sea center; and Q is the suspension flow discharge. Axis x is directed along the sea bottom toward its center. Settling of particles is not considered here.

The solution shows that the suspension flow is possible for any slope of the flow free surface or any slope of the sea bottom.

Our calculations show that all fine-grained terrigenous material delivered to the Black Sea continental slope base from river discharge may well be transported to the basin center by slow gravity driven suspension flows, tens of centimeters thick, moving above the sediment surface. This continuous seasonally cyclic lateral accumulation possibly generates the above mentioned varve sequences in which each double varve represents one year of depositional history: dark terrigenous mud laminae characterizing spring river floods and white nanno ooze laminae reflecting phytoplankton blooms.

Episodic (or periodic) instantaneous down-slope turbidity currents create not only sand layers in the abyssal plain section (Ross et al., 1978), but they also contribute to the Black Sea basin infilling with distal mud turbidites likely deposited by the lateral suspension flows described here. The distal turbidites are expressed in the varved sediment sections by thicker layers which are synchronous in different cores separated by up to 100 km (Ross and Degens, 1974). This suggests spreading of the thin flat suspension flows generated by remote turbidity currents over a wide area of the abyssal plain. The meeting line of the turbidity currents flowing into the sea from Turkey and Europe is described in a paper by Lericolais et al. (2013).

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Recent gas seepages within the territory of Azerbaijan: Distribution, composition, and intensity

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Keywords: carbonic acid, methane, discharge, volume, Azerbaijan

The territory of Azerbaijan is characterized by the widespread development of natural gas seepages, which can be divided into two groups: macro-flows and micro-emissions. The focused macro-flows of gas are related to mud volcanoes and mineral/thermal springs. Micro-emissions of gases occur everywhere and intensify locally over petroleum fields and mud volcanic areas.

Currently within the territory of Azerbaijan, about 1000 vents of mineral and thermal waters are known (Askerov, 1984), with a total water discharge of 105 million l/day. Gas represents the prevailing component, and it is subdivided into mainly methane (about 400 mineral springs), carbonaceous (about 350), and methane-nitrogenous (about 250). The spatial distribution of these waters reveals some regularities: (1) carbonaceous waters are located basically within the Lesser Caucasus mountains, and their origin supposedly relates to the metamorphism of carbonate rocks caused by young Quaternary volcanism; (2) methane waters occur basically at the eastern end of the Great Caucasus and Talysh mountains, connected mainly with processes of thermal destruction of organic matter. Fig.1 shows that gas-saturated waters are situated in fault zones of high permeability.

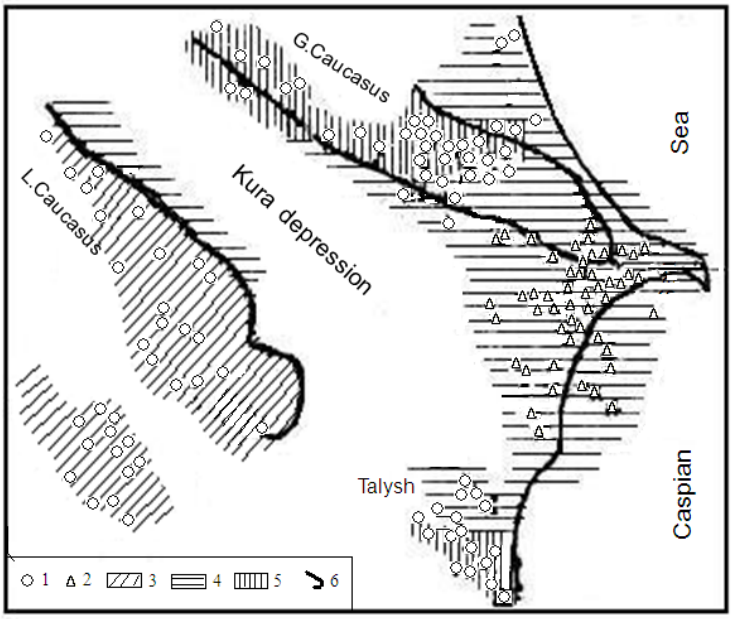

Figure 1. Schematic map of the distribution of natural gas seepages on Azerbaijan territory: 1–mineral and thermal springs; 2–mud volcanoes; 3–carbon dioxides; 4–methane gases; 5–methane-nitrogen gases; 6–boundaries of geotectonic units.

Average values of gas saturation are: for carbonaceous waters – 3.35 liter of gas per liter of water; methane waters – 0.17 l/l; methane-nitrogenous – 0.054 l/l.

The calculated total volume of gases discharged into the atmosphere by mineral and thermal springs from within the territory of Azerbaijan comes to about 50 million m^3/year, of which more than 90% is CO_2 and only about 6% is methane.

Most macro-discharges of methane are connected with the activity of mud volcanoes (MVs), which are widely developed in Azerbaijan. They are mainly located at the southeastern termination of the

Greater Caucasus mountains (about 190 MVs) and adjoining offshore Caspian seabed areas (more than 100 MVs). Gases from MVs are composed mainly of methane (up to 90–95%).

The annual macro-release of methane by mud volcanoes (both during quiet periods and during eruptions) is estimated to be 300 million m^3. Besides this, micro-escape of methane has been estimated annually at about 0.8 million m^3 from areas of developed MVs and nearby, and 0.6 million m^3 from the rest of the territory of Azerbaijan.

These approximate assessments of CH_4 and CO_2 discharged into the atmosphere by natural sources from within the territory of Azerbaijan are average-stationary. However, monitoring of the flows over time has revealed their variations (Fig. 2), which have been caused by the influences of modern geodynamic, geochemical, and thermodynamic processes within the subsurface.

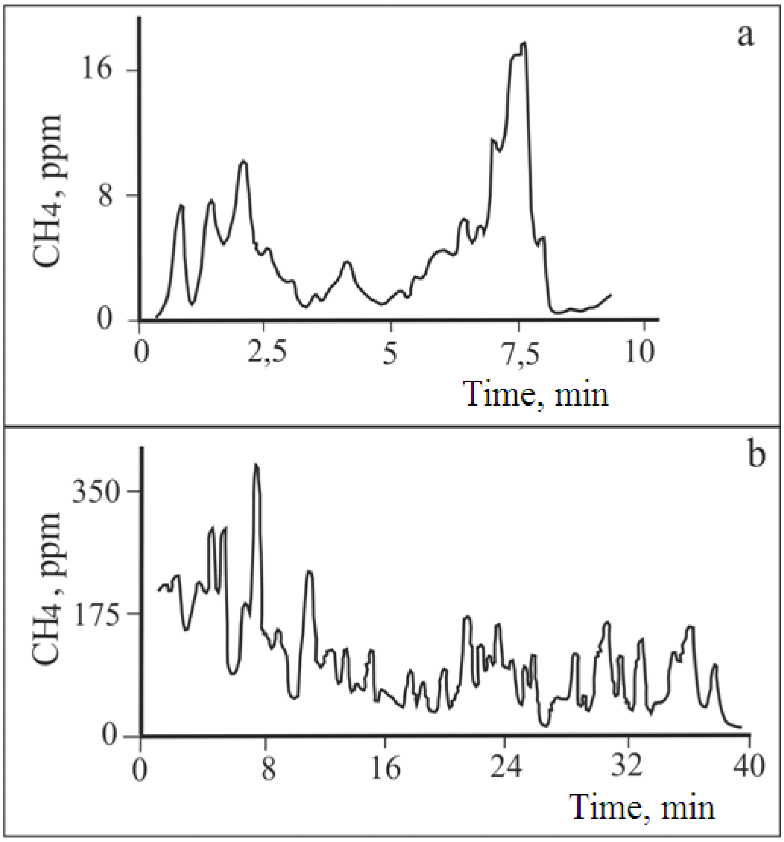

Figure 2. Changes over time in the atmospheric discharge of methane at (a) the Chukhuryurd mineral spring and (b) the Astrakhanka MV, Azerbaijan.

As is known, CO_2 and CH_4 are greenhouse gases, and therefore the calculations of gaseous discharges to the atmosphere from the territory of Azerbaijan are of interest in connection with assessments of their contribution to global climate change.

Acknowledgments

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Environmental changes in the Crimean Mountains during the last 45,000 years (paleontology and lithology from the Emine-Bair-Khosar cave)

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Keywords: mammals, paleopalynology, pollen surface samples, grain-size analysis, Late Pleistocene, Holocene

The karstic cave of Emine-Bair-Khosar is located in the north of the lower Chatyrdag limestone plateau (1000 m a.s.l.) in mountain meadow-steppe (the yayla). The studied section of the Museum Hall (5 m thick) is a fossil and sediment trap located below the vertical pit of the cave entrance. It has yielded several thousand bones of more than 50 vertebrate species from Pleniglacial, Late Glacial, and Holocene deposits (Vremir and Ridush, 2005; Ridush et al., 2013). Paleomagnetic studies have shown multiple climatic changes during the formation of these deposits (Bondar and Ridush, 2009), as well as the first results of pollen and grain-size analyses (Gerasimenko et al., 2010).

The reason for the modern treelessness of the yayla has been debated. One conclusion was that arboreal vegetation has been absent since the Last Glacial (Artiushenko and Mishnev, 1978) on the basis of pollen study of the short-profile Holocene yayla soils (no dating has been involved): whereas a macropaleobotanical study suggests that forested areas were reduced drastically under human impacts (Didukh, 1992). The position of the studied site near the upper limit of the slope forests, as well as high pollen frequencies in the cave deposits makes them especially indicative for studies of climatic change. The surface samples for pollen from different biocoenoses near the Emine-Bair-Khosar Cave have been analyzed in order to reinforce the interpretation of paleopalynological results from the cave sequence.

The oldest studied deposits of the cave (unit H) are ^{14}C-dated between 48,500±2000, >47,000 years, and 33,500±400 years BP. Presence or absence of pollen from broad-leaved trees shows the alternation of two ***Middle Pleniglacial*** interstadials and stadials. The unstable hydroclimatic regime is reflected in the formation of limestone blocks within silt or clay infilling. During the stadials, steppe dominated with abundant Asteraceae (particularly *Scorzonera)* and herbal xerophytes. The warmest interstadial occurred prior to 33,500±400 years BP, when clay content increased in the cave deposits, herbal xerophytes disappeared, forests spread, and broad-leaved trees (mainly *Carpinus*) could grow. At the end of the Middle Pleniglacial, the yayla was less forested, and trees were mainly represented by pine. These deposits contain the most abundant and diverse faunal assemblage in the profile. The small mammals include Insectivora, Chiroptera, Rodentia, and Lagomorpha. Rodents prevail, and they are dominated by arvicolids (*Arvicola*, *Ellobius*, *Eolagurus*, *Lagurus*, *Microtus*, and, particularly, *Microtus arvalis obscurus*). Sciurids (*Spermophilus* and *Marmota*), dipodids (*Sicista* and *Allactaga*), cricetids (*Cricetulus* and *Cricetus*), and murids (*Apodemus*) also occur. The lagomorphs include *Lepus* and *Ochotona*. Most of the carnivores are Mustelidae (*Martes* and *Mustela*), though a few bones of *Felis* and *Vulpes* occur. Red deer (*Cervus elaphus*) dominates among the ungulates, but steppe bison (*Bison priscus*) and *Saiga tatarica* are also numerous. There occur bones probably of a giant deer (*Megaloceros* sp.). Perissodactyla include large horse (*Equus ferus latipes*) and ass (*E. hydruntinus*) (van Asperen et al., 2012). Bones of woolly rhinoceros (*Coelodonta antiquitatis*) and another undetermined member of Rhinocerotidae have been found, as well as a few remains of *Mammuthus primigenius*. Birds are mainly represented by numerous remains of rock dove (*Columba livia*) and Alpine chough (*Pyrrhocorax graculus*). Open-country forms (*Microtus arvalis obscurus*, *M.*

oeconomus, *Arvicola amphibius*, *Lagurus europaeus*) dominated among the small mammals, including those that inhabit steppe and semidesert nowadays (*Marmota bobac*, *Spermophilus* sp., *S. subtilis*, *Arvicola major*, *Ellobius talpinus*, *Eolagurus luteus*, *Lagurus lagurus*, *Microtus* cf. *gregalis*, *C. migratorius*, *C. cricetus*, *O. pusilla*). Many species do not occur in Crimea at present (*O. pusilla*, *M. bobak*, *E. luteus*, *L. lagurus*, *Microtus* cf. *gregalis*, *M. oeconomus*). Steppe domination on the Chatyrdag plateau is also supported by the occurrence of *Vulpes corsac*, *Mammuthus primigenius*, *Mustela eversmanii*, *Equus ferus latipes*, *E. hydruntinus*, *C. antiquitatis*, *B. priscus*, and saiga. The occurrence of red deer and members of the genus *Apodemus* indicates the presence of forests in the area.

The ***Late Pleniglacial*** deposits (unit G) have the lowest clay content in the section. The number of angular limestone blocks and the 'loess' fraction (0.05–0.01 mm) increased and the lowest values for magnetic susceptibility are seen. The strongest reduction of arboreal vegetation occurred (the AP 14%). Steppe was dominated by representatives of the Asteraceae and Lamiaceae families. The incidence of *Betula* significantly increased (its pollen did not occur in the Holocene deposits). The climate was much cooler than during the Middle Pleniglacial, but the presence of a few *Carpinus* and *Acer* pollen grains might indicate the existence of their refugia on the mountain slopes. Voles, with dominant *Microtus arvalis obscurus*, prevailed in the faunal assemblage. *Spermophilus*, *Sicista*, and *Apodemus* also occurred among the rodents. The lagomorphs included *Lepus* and *Ochotona*, and a few bones of insectivores occur. Carnivores became much less abundant: only remains of *Lynx lynx* and *Vulpes* sp. have been found. Red deer and saiga dominated among the ungulates. Bones of *Megaloceros giganteus*, steppe bison, unidentified members of *Capra,* horse, woolly rhinoceros, and mammoth were very few (probably redeposited?). The scarcity of large mammal bones could indicate that the cave entrance was frequently closed by a snow 'cork'.

The ***Late Glacial*** (unit F, ^{14}C dates 10,490±170, 12,050±60 BP) is marked by a strong increase in *Ephedra*, which is typical for this time. The incidence of forest was similar to that of the present, but the role of broad-leaved trees was less and *Pinus* dominated. *Carpinus betulus* was more common among the broad-leaved trees, which also included *Fagus* and *Ulmus. Betula* and *Alnus* were more abundant than broad-leaved trees. Meadow components became more important in the mountain steppe. The role of Asteraceae and Lamiaceae became less through an increase in Poaceae and Cyperaceae. All of these show that the climate was cooler than at present, but rather wet. At the end of the interval, herbal xerophytes noticeably increased (the Younger Dryas?). A further decrease in mammal diversity occurs in unit F. Rodents were represented only by voles and the European hamster (*C. cricetus*). Open-country forms dominated among the small mammals, including typical steppe species. *Microtus arvalis obscurus* dominates, and *C. cricetus* occurred (both present in the extant fauna). On the other hand, *E. luteus*, *L. lagurus*, and *Microtus* cf. *agrestis* are extinct in Crimea today. Few remains of insectivores and *Lepus* have been found. The other vertebrates include *Saiga* and unidentified birds. It seems that this faunal complex existed during the dry time of the Younger Dryas.

At the ***beginning of the Holocene*** (units E and D), forests with broad-leaved species spread and spore plants became abundant (up to 52% palynomorphs). The disappearance of *Betula* and reduction of herbal xerophytes are indicative. The grey-brown and more clayey deposits contain a small amount of clastic debris. This warm and wet phase was then replaced by a cooler and much drier one when the debris interlayer was formed (the Late Boreal cooling?). The maximum spread of broad-leaved trees (*Carpinus*, *Fagus*, and *Ulmus*) and mesophytic herbs (Ranunculaceae and Rosaceae), as well as the maximum clay content and the drop in 'loess fraction' (27%) in the deposits, may correspond to the ***Atlantic optimum***. The amount of debris became much smaller, and the indices of magnetic susceptibility increased. The climate was warmer and wetter than nowadays. The faunal assemblage indicates that during the formation of unit E, open steppe existed (the occurrence the European hamster and the common vole, and particularly the presence of species indicative of continental climate which are now absent in the Crimean fauna: *L. lagurus* and *E. luteus*). Unit D contains numerous remains of an unidentified hare and a few bones of the corsac fox (absent from the contemporary fauna of Crimea) and red deer. This indicates co-occurence of steppe and forest at that time.

A progressive increase in climatic aridity occurred during the formation of units B and C. At that time, *Pinus* spread at the expense of broad-leaved trees, *Quercus* moved higher in the mountains, and the range of mesophytic *Carpinus* and *Fagus* contracted. Herbal xerophytes became significant in the yayla steppe, though mesophytic herbs still prevailed. The content of dust strongly increased (58%) in the sediments and magnetic susceptibility dropped at the top of the unit, which is related to the ***Late Subboreal*** (the paleomagnetic date 2,800 years BP). This arid phase is also well pronounced in the Ukrainian steppe (Gerasimenko, 1997). Units B and C contain remains of birds and a few mammalian bones (insectivores, bats, rodents, lagomorphs, and carnivores). Most of the taxa are living today in various landscapes, ranging from steppe to temperate forests.

The ***Subatlantic*** is recorded in unit A whose deposits are strongly enriched in humus. This corresponds to the strongest humus accumulation in the Subatlantic soils of the Ukrainian steppe. In the lower part of the unit, the AP (69%), herbal mesophyte, and spore counts are higher than nowadays, though the pollen percentages of broad-leaved taxa are less. This indicates a wet and relatively cool climatic phase which may correspond to the Early Subatlantic. The highest indices of magnetic susceptibility in the middle part of the unit might represent the warm Middle Subatlantic. At the top of the unit, the AP counts become similar to present-day ones, but those of broad-leaved trees are much less, and the maximum of Polypodiaceae (76%) is registered. This, together with a strong increase in the sand content, gives evidence of high humidity. The decrease in pollen production by broad-leaved trees might indicate the cooling of the 'Little Ice Age' (XIII–XVII centuries). The fauna from unit A mainly includes components of the extant Crimean fauna (e.g., *Microtus arvalis obscurus*, *A. flavicollis*). The habitat preferences of the mammals from this unit indicate co-occurrence of open landscapes and temperate forests.

The data obtained show that since the Middle Pleniglacial, both open steppe landscapes and forests existed in the Chatyrdag yayla. Thus, the modern treelessness of the yayla seems to be the result of human impacts.

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Paleogeographical and geoarchaeological reconstruction of the western Black Sea zone during the Quaternary

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Keywords: transgressive-regressive cycles, Quaternary sediments, climatic and sea-level changes, prehistory, submerged settlements

Introduction

This paper discusses the paleogeographical reconstruction of two major morphological units, the coastal zone and the open shelf, which are genetically connected. A synthesized reconstruction of the Quaternary development of the coast and the shelf, two neighboring geomorphological units, is described in the paper. Both units are genetically connected and form part of the western Black Sea zone. Nowadays, they are differentiated in the contemporary coastline, however, in the geohistorical development of the Black Sea deep-sea basin during Neogene-Quaternary time, this coast-shelf zone was repeatedly at times either land, or, at other times, submerged under water. It has always been very dynamic. The present research establishes a new complex approach to reconstruction of the dynamic paleogeography of the Black Sea coast and shelf from the beginning of the Quaternary 2.6 Ma (Head et al., 2008) to contemporary times.

Marine Pleistocene and Holocene sediments within the Black Sea zone are of interest to the scientific community. Geomorphological description and biostratigraphic analysis of the onshore marine terrace complexes are a key for determining the ancient coastline on the one hand, and, on the other hand, the marine Pleistocene and Holocene sediments correlate by age and other characteristics with sediments from the shelf. This can prove that the formation of both onshore and offshore sediments is a result of the same paleogeographic events in the Black Sea basin.

Methodology

The characteristic feature of this paper is that the data of numerous terrestrial and marine expeditions have been summarized with an aim to reconstruct the development of the Bulgarian Black Sea coast and shelf. The climatic and sea-level changes of the Black Sea during the Quaternary have been traced out on the basis of the analysis of the transgressive-regressive cycles, terrace complexes along the coastline, and lithologic and biostratigraphic research on molluscan fauna and palynological data (Hristova 2006).

The evidence for the investigation comprises coast and shelf samples from geological structures over a substantial range of geomorphological locations: (N) Northern; (A) Aprilska; (E) Elizavetinska; (SE) Samotino East; (SS) Samotino Sea; (YG) Yurii Godin geological structures; the mouth of Batova River, Kamchia River, Fandaklijska River, Aheloj River, Durankulak Lake, and Shabla-Ezeretz Lake.

The cores of several drill-holes with a length of 30 to 50 m beneath the seafloor are described lithologically and stratigraphically. A complex approach is applied to studying the cores, combining biostratigraphic, geomorphologic, and lithologic methods, as well radiocarbon and archaeological data especially for Holocene sediments. Such a complex analysis yields results with a high reliability.

Results

A complete paleogeographic reconstruction of the Quaternary evolution of the Bulgarian Black Sea zone was made. The established stratigraphic sequence represents levels of the Pleistocene and Holocene series of the Quaternary system. In the chronostratigraphic scheme employed for the regional stages and substages on the Bulgarian Black Sea shelf, the Pleistocene series is represented by: (1) the Chaudinian regional stage (Lower Pleistocene); (2) the Old Euxinian and Uzunlarian regional stages (Middle Pleistocene); and (3) the Karangatian and Neoeuxinian regional stages (Upper

Pleistocene). The Holocene series is represented by the sediments of the Chernomorian regional stage. It is divided into the Oldchernomorian substage and the Newchernomorian substage. A correlation between the units of the coastal zone and shelf was made, and it was concluded that features within the both areas are the result of the same transgression-regression cycles of the Quaternary evolution of the Black Sea.

The paleoecological conditions of the Black Sea coastal area during the Holocene have been reconstructed from the point of view of the submerged prehistoric settlements dating from the Eneolithic period and the Early Bronze Age. Humid zones of the Earth are extremely important as natural habitats that provide shelter to a great variety of species. Along the western Black Sea coast, littoral areas (lakes, lagoons, and deltas) were formed during the post-glacial transgression. As a result of this post-glacial transgression, the Black Sea was transformed from freshwater lakes into a marine basin with paleocological features close to the contemporary characteristics: increase in salinity of about 19‰, increase in temperature and humidity. The characteristics of this climatic optimum are conserved in the marine Holocene sediments. The established settlements have been analyzed from their geomorphological position with the methodology of underwater archaeology. A number of submerged prehistoric settlements are known along the western coast of the Black Sea. Geomorphologic analysis and underwater archaeology indicates that they existed from the Eneolithic period and Early Bronze Age (between 6500–4000 BP). This has also been proven by the Holocene sea-level curve in the western part of the Black Sea. In the peculiar context along the western Black Sea coast, much recent research has shown that at the beginning of the Holocene, the Black Sea was disconnected from the Mediterranean. This connection occurred sometime around 6700–6500 BC. This phenomenon resulted in a rapid rise in sea level and consequently in “dramatic” changes in the coastline geometry and fluvial dynamics. These modifications probably affected the capacities of these coastlines and deltaic areas to produce and maintain biodiversity. The general worldwide sea-level rise was and still is a major source of social, geographic, and environmental transformations.

Throughout the Ice Ages, sea levels were mostly lower than present by as much as 150 m, creating extensive coastal landscapes attractive to human settlement. Between 16,000 and 6000 years ago, most of this territory was drowned by sea-level rise following the last Ice Age, transforming the geographic and environmental context of human development. This drowned landscape preserves valuable sedimentary archives of long-term environmental and climatic changes, and an increasing number of submerged archaeological remains that document human response to this rapidly changing environment.

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Some geological-geomorphological, geochronological, and biostratigraphic evidence of Azov Sea level changes in the Middle and Late Holocene

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Keywords: Holocene, transgression, regression, coastal bars, diatom analysis, radiocarbon dating

There are two opposite points of view on the problem of the Middle and Late Holocene fluctuations (last 6 ka) in sea level of the Azov-Black Sea region and related basins. One has been to postulate many different oscillations (Balabanov and Izmailov, 1988; etc). The other states that there was a small (within a few meters) and gradual transgressive rise without any oscillations (Brückner et al., 2010; etc). Studies on this issue in the open and coastal waters of the Sea of Azov may significantly improve our understanding of past conditions in the area and contribute to the resolution of this contradiction. The main feature of the Sea of Azov is that it is a non-tidal, shallow water basin, and it conditions large spatial shifts of coastline during sea-level fluctuations. The Sea of Azov is also relatively highly productive, and the sediments are saturated with different organic matter. The qualitative and quantitative changes in these bio-organic sediments can be estimated, and radiocarbon and other methods of dating can be conducted. Most of the basin is located within a territory with stable tectonic conditions, which is also very important for paleo-reconstructions. A series of data obtained during recent studies, and conclusions made on their basis, demonstrate our point of view on the considered issue. Our perspective is described below.

Transgressive coastlines of the period in question have been thoroughly studied along the eastern coast of the basin: in the Kuban River delta (Izmailov, 2010; Izmailov et al., 2011). A complex system of coastal swells (subaerial sand bars), which are the facies analogue of the current beach and located in the delta depression dozens of kilometers off the present seashore, has been mapped within the territory. Coastal swells are composed of sand and shell material. The abundance of shell material offers a good opportunity for paleontological, paleoecological, and geochronological studies. The entire system of coastal bars displayed in the current relief is divided into two main generations: the most ancient one is the Dzhemetinian stage, and the second is Nymphaean stage. The stages are separated by the well-known period of the Phanagorian regression.

Coastal bars of the Dzhemetinian stage are characterized by a rather complex pattern. Mapping of these forms resulted in the identification of 4–5 independent generations, each of which corresponds to regressive-transgressive phases of the second order. The latter is confirmed by frequent disordered connection of separate bars to each other, thus indicating that abrasion took place in the older generations during the formation of subsequent cycles. The described forms were registered at the maximum distance of 35 km beyond the current seashore. The absolute elevation of bars of the same age varies from 0.5–0.6 m to 2.5–2.6 m and some local elevations are related to remnants of eolian accumulation. The analysis of elevations allowed a reconstruction of the current location of the shorelines for the stage in question to 0±1m in height. The molluscan fauna from the bottom sediments characterize the conditions at the time as having slightly higher salinity compared to the current salinity of the Sea of Azov (Kazantip layers). The most abundant species within the samples include *Cerastoderma glaucum* (Poir.), *Mytilus galloprovincialis* (Lam.), *Chione gallina* L., *Paphia* *discrepans* Mil., *Solen vagina* L., *Pholas dactilus* L., *Mytilaster lineatus* (Gm. in L.), *Abra ovata* (Phil.), *Gastrana fragilis* L., *Nassarius reticulatus* (L.), *Tellina* sp., etc. Radiocarbon dating of the Dzhemetinian bars is confirmed by 10 dating sets in the range of 5.8 to 2.7 ka (the calibrated age was 6.7–2.8 ka) (Izmailov et al., 2010). Of special interest is a series of the most ancient dates from 5.8 to 5.2 ka which clearly indicate that the sea level corresponded to the current one closely even at that period. Control dating at an independent laboratory showed similar results.

The system of fairly distinct and better preserved coastal bars extending up to 14 km off the current seashore was related to the Nymphaean stage. Up to 3–4 independent generations of bars were observed, and 16 radiocarbon dates ranging from 2.3 to 0.5 ka (the calibrated age was 2.4–0.56 ka) were obtained (Izmailov, 2010). The current altitude location of the transgressive coastal lines of the Nymphaean stage was also assessed to the nearest 0±1m. The influence of tectonic deformations on the elevations of both Dzhemetinian and Nymphaean shorelines is insignificant (Izmailov, 2013). A loss of molluscan diversity is observed in the younger bars. At the same time, during the development of both the Kazantip and Novo-Azov stages, recurrent intervals of increase and decrease in molluscan faunal diversity were observed.

The extensive research of recent years has gradually increased the database on the regressive stages during the Middle and especially Late Holocene of the Sea of Azov (Matishov et al., 2007, 2009; Zaitsev and Zelenshchikov, 2009; Matishov et al., 2013; etc). Complexity in the sediment cores of that period was observed during the detailed investigation of several wells: differing sedimentation rates in vertical section that tend to increase into transgressive phases, regular changes in palynological (pollen) communities, etc. One of the effective methods for analysis of transgressive and regressive stages of the development of the sea is the study of fossil diatom algae (Kovaleva and Zolotareva, 2013).

The diatom analysis conducted for the Novo-Azov sediments, from the Phanagorian regression and Nymphaean transgression (the period from 3.1 ka to present) over different areas of the Sea of Azov, revealed common trends in the changes shown by microalgae species composition. Alternation of layers, typical of the Novo-Azov sediments, was observed in all cores. The layers of *Actinocyclus octonarius* Ehr., *Actinoptychus senarius* (Ehr.) or species of the genus *Chaetoceros* sp. alternately dominate in the cores (Kovaleva, 2006, 2007). The contrasting ecological characteristics of these species allow them to be used as indicators of sea-level change. The dominance of *A. octonarius* and *A. senarius* in the deposits allows one to assume that there was a lower sea level during that period, while the increasing concentration of spores of marine genera (*Chaetoceros*) in the sediments marks stages of the sea with increased salinity, high hydrodynamic activity, and increased sea level (Kovaleva and Zolotareva, 2013).

Six biostratigraphic zones were determined to compare the results of diatom analysis with radiocarbon data. Each zone corresponds to a transgressive or regressive stage of the Sea of Azov. Zone 1 (the calibrated age was 3110±170 to 1900±120 years ago) corresponds to the end of the Dzhemetinian stage and mainly to the Phanagorian regression (both in the western and southeastern areas). This zone is characterized by a high frequency of *A. octonarius* valves which, due to the specific features of the species distribution, indicate that the regression took place during the period. In two cores, three subzones (a, b, c) were registered. Subzone b is characterized by a sharp increase in *Chaetoceros* spores, thus marking the period of short-term sea-level rise. We may assume that it could already be the Nymphaean 1 transgressive phase. Zone 2 (1730±100 to 1310±200 years ago) corresponds to the main phases of the Nymphaean transgression (Nymphaean 2–3) and is characterized by the predominance of *Chaetoceros* spores in the samples, thus indicating possible sea-level rise. Zone 3 (about 800±90 to 600±60 years ago) coincides with a regressive stage in the Sea of Azov's development, as *A. octonarius* predominates in the bottom sediments of the period, and *Chaetoceros* spores decrease. This zone was observed in 3 cores and probably corresponds to the Korsun regression. Transgressive and regressive phases, corresponding to zones 4, 5, and 6 were observed in almost all the cores according to the results of the diatom analysis. The transgression in Zone 4 was registered in 3 cores, but radiocarbon dating was done only for one of them (340±140 years, Nymphaean 4?). Zone 5 (characterized by a decreasing sea level) was registered in two cores. The age of these deposits is less than 200 years and might correspond to the regression of the Little Ice Age.

Zone 6, according to diatom analysis data, is characterized by a sea-level rise and was clearly registered in 3 cores, though radiocarbon dating was not performed. This zone probably demonstrates the changes that take place currently, corresponding to the current Sea of Azov level. Thus, we could note that the change of climatic and, correspondingly, hydrological conditions during the Late Holocene (the last 3100 years) directly impacted the gradual change of the dominating species of diatom algae (Kovaleva, 2010; Kovaleva and Zolotareva, 2013).

Thus, we conclude that numerous contrasting fluctuations in the level of the Sea of Azov took place during the entire period, with elevations corresponding to the current sea level during the transgressive phases but with significant decreases during the regressive phases. The stratification, chronology, and amplitudes of these fluctuations still need to be clarified, however, we can conclude that there is, for example, a definite correlation in time between the maximum of the Nymphaean transgression, which formed the Kazach'ya Ridge located 14 km off the current seashore (Izmailov, 2010) and the formation of sediments showing a dominance of diatom algae (*Chaeteceros*) spores, indicating periods of sea-level rise. Both methods indicated the occurrence of the Phanagorian regression.

Taking into account that our materials demonstrate good correlation of the results obtained by different (alternative) methods, we assume that future scientific cooperation in the field will be promising.

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Relation of Colchis coastal peat bog lithological-facies peculiarities in the Holocene with fluctuations in Black Sea level

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In the Colchis coastal zone (Georgian Black Sea coast), in the immediate vicinity of the sea, for nearly 35 km, deep peat bogs are located in the areas of Kobuleti, Grigoleti, Maltakva, Imnati, Nabada, Churia, and Anaklian, etc., separated from each other by river beds. Lithological-facies conditions during the development of the coastal wetlands have been quite accurately studied to identify the peat industrial reserves and categories on the basis of the complex analysis of drilling data (tens of 5–18 m deep wells) (Neishtadt et al., 1965; Georgian Geological Department, 1979; Janelidze, 1980; Bogolyubova and Kotov, 1990; Janelidze et al., 2007a,b).

With respect to the problem of Black Sea level fluctuations in Holocene, the following is remarkable from the particularities of the Colchis coastal wetlands:

Their location is near the sea at a distance of 100–300 m from the coastline and at a height of 0.2–0.5 m above sea level;

Separation of the wetlands from the sea by a line of sand-pebble hillocks (dunes) occurred 4000–6000 years ago; the height of the hillocks varies between 2–5 meters;

Development of a continuous peat horizon in the wetlands grew to a thickness of 4–12 m, the greater part of which is sunk below sea level;

Sequence of wood and peat layers with sedge, sphagnum, and herbaceous peat layers in the geological sections of the wetlands peripheral zone may have been caused by changes in the wetlands' hydrological regime (rise or fall of the erosion basis in relation to sea-level fluctuations);

Bronze Age settlements were located under a 2–3 m thick peat layer within the inner periphery zone of the wetlands;

The oldest peat layers (the deepest) yielded a radiocarbon age of 5500–6500 years.

Favorable factors for development of the Colchis coastal wetlands are as follows:

- Abundant atmospheric precipitation (1500–2500 mm per year);
- Development of the coastal plain relief with an essentially flat but slightly partitioned surface located at a height of 0.2–0.5 m above sea level underlain by impermeable clay horizons;
- Dense hydrographic network formed by the rivers full of water;
- Rich vegetation cover developed under conditions of humid and warm climate.

These facts lead us to the conclusion that the intense development of peat bogs in the Colchis coastal zone of the Kolkhetis seaside was conditioned by the Black Sea Holocene transgression along with the joint action of other factors contributing to water logging. Sea-level rise (and rise of the erosion basis) slowed surface water drainage dramatically on the slightly inclined flat coastal plains in the direction of the sea, and stepped up their ponding along the coastline, thus contributing to the development of the water logging process. The zone of longshore hillocks occurred in the maximum development phase (4000–6000 years ago) of the New Black Sea Transgression, elevated the surface of the coastal plain by a few meters and intensified even more the surface water flooding and, consequently, the water logging process directly along the coastline.

The results of the interpretation of (1) lithological-facies analysis within the Colchis coastal wetlands, (2) the buried archaeological materials, and (3) radiocarbon dating of peat layers, compared with data published by researchers on Black Sea level fluctuations in the second half of the Holocene (the last 6000 years), prove that the fluctuations were of a much lesser extent (Arslanov et al., 1982; Shilik, 1977).

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Agroforest Plantations as a method of increasing GHG sequestration capacity and reducing man-made impacts upon the natural forest resources of Northeastern Azerbaijan

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Keywords: climate change, greenhouse gases, mitigation, reforestation, energy

Climate change is one of the most critical global environmental challenges. Unlike naturally driven climatic fluctuations, climate change is connected to a number of manmade factors related to destructive anthropogenic activities. Another hallmark of climate change consists in its inevitability: caused by manmade activities, negative climatic processes occur too fast to let nature adapt to the ongoing changes.

Climate change is mainly caused by air emissions of GHG (mainly CO_2) emanating from the various sectors of heavy industry, agriculture, and transport. Additionally, the degradation of CO_2 absorbing forests is known as the most important indirect factor in the process. Therefore, there are two prospective directions for battling climate change (Initial Communication …, 2000):

Reduction of GHG emission levels via the limiting of the volumes of actual emissions as well as the introduction of environment friendly industrial and agricultural technologies;

Increasing the natural GHG sequestration capacity through the conservation and rehabilitation of the world's forest resources, including the establishment of agroforest plantations as a tool for satisfying the demand for commercial timber and preserving natural forests from cuts.

Agroforests are the organized plantations of fast-growing trees with short cutting periods. The goal of such plantations consists in usage of the produced timber to satisfy relevant commercial needs for various stakeholders. Normally, such plantations are established on recultivated deforested lands divided into a number of rows and planted with saplings of the fast-growing trees. The most suitable species of wood to be planted in the agroforest are poplar, which, already in their fifth year, reach the commercial parameters of cubic capacity (0.12 m^3), bore height (10.5 m), and diameter (12–16 cm). Sustainability of agroforest plantations is achieved through annual planting of new saplings to replace the cut trees.

Agroforest plantations have the following environmental and socio-economic advantages:

- Provision of local population and businesses with alternative timber resources and firewood, achieved through the regular cutting of trees grown at the plantations;
- Creation of additional GHG sequestration capacities via an increase in the areas covered by forests;
- Reduction of the manmade impact upon natural forest resources, resulting in the latter's preservation and rehabilitation.
- In Azerbaijan, there is great potential for the development of agroforest plantations. Since gaining its national independence, the country has gone through a serious economic and energy crisis, among others, leading to illegal cutting of the natural forest resources. Despite this, today the situation has improved, and the need for firewood isn't as high as it used to be in the past. Still, there is a local demand for timber. Such demand calls for providing local stakeholders with the alternative wood resources which can be successfully produced by the agroforest plantations.
- There are three potential ways to develop such plantations in Azerbaijan:
- Convincing local farmers to take an interest in producing the alternative wood resources on their private lands;

- Establishment of agroforest plantations on the deforested lands belonging to the National Forest Fund;
- Rehabilitation of degraded areas which aren't part of the agricultural lands and planting them with fast-growing woody species.

The Public Association for Sustainable Development Assistance "Chevra" was the first organization to establish an agroforest plantation in Azerbaijan. "Chevra" is a local environmental NGO that was founded in 1999 and has since then, implemented many projects addressing the issues of environmental protection, awareness raising, education, climate change adaptation, and emergency management.

Back in 2004, "Chevra" had initiated the CIDA funded project to develop an agroforest plantation "Govag" in Shabran district of Northeastern Azerbaijan. Six ha of degraded municipal lands in Devechi municipality were chosen as the project area. After necessary earthworks and land preparation, 17,500 species of local and hybrid poplar were planted to form the basis for a pilot agroforest plantation. The project ended in 2005 with the construction of an administrative office for “Govag” and pending the first year of the young plantation’s growth.

A second project started in 2006 with funding support from CEP. Within the framework of the project, completed in the middle of 2007, 20,000 more saplings of poplar were planted in an area of another 6 ha of rehabilitated land. The second project helped double the size of the agroforest plantation.

As of 2011, i.e., after 5 years of growth of the young poplars (the age when trees become marketable), the plantation of 37,500 trees started producing according to the following annual production capacity:

Annually produced firewood capable of satisfying the needs of up to 70 local households.

735 tons of CO_2 sequestered in addition to the region’s existing natural and man-made green resources.

Since the 6th year of its operation, one row out of 5 strips of the planted trees (750 m^3 of wood) are logged annually and sold to the local stakeholders at below-market prices. New saplings are planted to replace the cut trees to ensure the plantation's sustainability.

Successful operation of the "Govag" agroforest plantation produced the following environmental and socio-economic benefits:

- Conservation of the respective volumes of the region’s natural forest resources as a result of reduced illegal logging by local communities;
- Partial mitigation of climate change impacts via the preserved and added CO_2 sequestration capacities;
- Mitigation of the desertification process through the rehabilitation of lands subject to a man-made degradation;
- Opportunities for local communities to obtain firewood at a reasonable price that encourages abandoning efforts related to illegal logging and poaching;
- Opening of additional job opportunities for people engaged in the plantation’s operation;
- Development of additional recreation capacity for the local population.

The environmental effect of the plantation established by "Chevra" is geographically small, but the described success story creates grounds for its replication in the other parts of Azerbaijan, which in total would benefit the task of country's environmental rehabilitation and national-level climate change mitigation mechanism.

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Rehabilitation of the geoecological balance on the western coastal zone of the Caspian Sea: Assessment and remediation of radioactively- and oil-contaminated lands (case of Azerbaijan)

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The territory of Absheron is under intensive technogenic impacts related to past and ongoing operations of oil wells as well as other activities of the oil and petrochemistry industry. Besides this, thousands of hectares of the peninsula's land, water, and sea ecosystems are polluted with oil and oil products because of extensive production methods used before the revolution without any protective measures. Mitigation of the results of such pollution is very important for the Azerbaijan Government, which decided to take adequate measures to improve the environmental situation in Absheron. According to a Presidential Decree from September 8, 2006, the “Complex Plan for improvement of the ecological situation in Azerbaijan Republic for 2006–2010” was launched to address a considerable number of environmental concerns.

One of the Plan's components was assigned to a newly established Ministry of Emergency Situations. The project was named "Deactivation of Radioactive Charcoal Wastes emerged as a result of iodine-bromine production in Surakhani district of Baku," and it targeted extremely contaminated production facilities of the former Baku Iodine Plant.

Contamination of the plant, which was operational throughout the period between 1930s and 1990s, is one of the most critical environmental concerns of the Absheron peninsula. The plant consisted of two production sites situated next to the Ramani and Surakhani settlements, respectively. A neighborhood of heavily populated areas, it experienced a tremendous threat to public health when the plants were operational, but it continues to receive a negative impact even now after the closure of business. The total area occupied by the plant equaled 32.5 ha of land, 4.3 ha of which belonged to Ramani and 28.2 ha to the Surakhani production sites.

According to practiced technologies, iodine was produced from stratal waters, which surfaced together with oil extracted from the Balakhani-Sabunchu-Ramani and Gala oilfields. These waters used to be transported to the accumulation reservoirs and were later used as the source for iodine extraction. Plants deployed activated charcoal as absorbents, which, among the other elements, also absorbed different radionuclides, mainly isotopes Ra-226, Ra-228, U-235, U-238, Th-232, and K-40. In violation of the then existing technical rules of the Soviet Union, the used radioactive charcoal was stored at the production sites without proper maintenance or disposal.

As a result, considerable amounts of radioactive charcoal waste remained in both the Surakhani and Ramani facilities with the level of activity varying between 300–1,000 and 10,000–13,000 Bq/kg. According to both national standards and International Atomic Energy Agency’s (IAEA) waste classification scheme and guidance, the accumulated charcoal waste belonged to a category of (Radium-Bearing) Long-Lived Low-Level Waste (LLW-LL).

Considerable contamination by the abovementioned isotopes was also observed in silt and chemical sediments deposited within the inner walls of the asbestos pipelines used for drainage of processed oil water. Pipelines transported the used water together with other liquid wastes back into the reservoirs or into the neighboring industrial waste collectors, such as the Hovsan collector.

Unfortunately, no measures were undertaken to isolate or dispose of the charcoal since plants were abandoned in 1995–1996. On the contrary, due to the negligence of the plants’ administration, the valuable equipment and infrastructure were disassembled and removed from both production sites, while some parts of the remaining radioactive charcoal have been withdrawn by third parties for reuse. Finer-grained charcoal material, subject primarily to wind-borne transport, has spread over a much wider area at the two sites, relative to the original locations of the charcoal waste piles.

An initial site assessment run by MES (the Ministry of Emergency Situations) concluded that the evaluable on-surface volumes of charcoal waste from both sites amounted to 32,000 m^3, while the level of waste radioactivity averaged 15–60 microroentgens/hour, with anomaly spots reaching 600 microroentgens/hour and even more. On the other hand, the total volume of the industrial and other solid waste from the two sites made up 19,000 m^3, 11,000 m^3 of which is due to the charcoal materials (Preliminary Site Characterization Report, 2008).

In 2007, based on the initial assessment, MES engaged the subcontractor organizations to plan the required remediation work and to develop their Environmental Impact Assessment and Feasibility Study. Pending the completion of planning activities, work was launched in 2011 aiming at complete rehabilitation of the radioactively contaminated lands of the former iodine production facilities.

Remediation work was realized following consequent milestones (Feasibility Study, 2008):

- A special subsurface disposal facility for the low-level radioactive wastes was constructed on the special polygon of "Isotope" (MES), capable of receiving up to 100,000 m^3 of waste;
- Complete volumes of charcoal were collected from both production sites, safely transported to the polygon and buried at the disposal facility;
- The soil polluted with oil and oil products, bitumen, and black oil was collected from the production sites and delivered to the special disposal facility;
- The plants' manufacturing buildings, structures, and equipment were dismantled and delivered to a special landfill;
- Soil grounds, garbage, and asphalt concrete layer were gathered and delivered to the assigned landfill;
- Pending the completion of clean-up activities, efforts were undertaken to remediate the land's biological productivity until it became completely useful for purposes of urban planning and agriculture.

About 28.2 ha of the remediated lands of the former Surakhani production site were completely returned to the economic cycle and handed over to the Surakhani municipality to be used during future extension of the settlement. 4.3 ha of the Ramani production site were turned into a modern park used as a recreation facility for the settlement's local population (Environmental Impact Assessment, 2008).

The experience gained by MES during the remediation of the polluted lands of the Baku Iodine Plant is currently being applied to the cleanup of the abandoned Iodine Factory in Neftchala.

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Modern active tectonics in the convergence zone between the North and South Caucasian microplates: The Eastern Caucasus-Caspian Megadepression (Azerbaijan)

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The transition area between the Eastern Caucasus and Caspian Megadepression corresponds to a periclinal submergence zone of the mountain folded structure of the Greater Caucasus under the Pliocene-Holocene sedimentary complex of the Caspian Megabasin. Being a part of the Alpine-Himalayan fold belt, the Greater Caucasus formed during the alpine stage of tectogenesis under geodynamic conditions of convergent interactions between the Northern and Southern Caucasus continental microplates (Baranov et al., 1990). This process was accompanied by pseudo-subduction of the first plate under the second, with formation of an allochthonous accretion prism above the underthrust zone (Kangarli, 2012). The modern folding and napping structure of the orogeny formed as a result of the horizontal movements of different phases and subphases of alpine tectogenesis, which are represented by the Late Cimmerian-Wallachian tectonic phases within Azerbaijani territory (Geologiia Azerbaidzhana, 2005).

Limited by meridional fault-slip zones, the Caspian Megadepression presents itself as a young structure that layered onto a sublatitudinal convergent zone and developed during the Late Miocene (10 million years ago) as a flexure zone between two indenters, which actively moved northwards provoking their separation from the African continent and Arabian plate in the west and secession from the Central Iranian plate of the Lut block in the east (Khain and Chekhovich, 2003).

The movement of the Arabian plate to the north supports the accumulation of horizontal stress in the current stage of tectogenesis. The current process reveals itself both in the fragmentation of the Southern and Northern Caucasus continental microplates into blocks of various sizes along the general and anti-Caucasus trending faults, and in the horizontal and vertical movements within the convergence zone. All these factors define the complexity of the geodynamic condition revealed here, in which recent seismic activity of the transitional zone has become apparent. There exist seismic zones here that are confined both to a convergence line and to the fault zones that confine the Caspian Megadepression or complicate its inner structure.

Under conditions of lateral compression, the small-size dynamic blocks that form the inner structure of the earth's crust in the transitional zone suggest a basis for formation of the transpressive deformations. These deformations combine, moving along the border of the transverse dislocations with the compression structures like the Main Caucasus strike faults in a trend of convergent (pseudo-subduction) interaction between the Southern and Northern Caucasus continental microplates. During this process, multiple elastic stress accumulation zones develop that are confined to the above mentioned dislocations and their connection knots. Once the breaking point of the rock is exceeded by the accumulated elastic deformations, energy is released yielding fragile destructions (stick-slip mechanism) in such tectonically vulnerable transition zones.

Data of real-time GPS measurement of the regional geodynamics indicates modern tectonic activity in the convergence zone of the North and South Caucasian microplates. The ongoing pseudo-subduction interaction of the plates is also indicated by data from regional seismicity, which is irregularly distributed by depth (foci levels at 2–6, 8–12, 17–22, and 25–45 km). Horizontal and vertical seismic zoning is explained by crustal's block divisibility and tectonic stratification, within the structure of which the earthquake foci are mainly confined to the crossing nodes of differently oriented ruptures, or to the planes of deep tectonic disruptions and lateral displacements along unstable contacts of the substantial complexes with various degrees of competence. At the present stage of tectogenesis, the most seismically active are the structures of the northern flank of the South Caucasian microplate, controlled by the Ganyx-Ayrichay-Alyat deep thrust with “General Caucasus” spread in the west, and sub-meridian right-lateral strike slip zone of the Western Caspian fault in the east of the Azerbaijani part of the Greater Caucasus. This fact is particularly proven by earthquakes that took place between May and December, 2012, in Zagatala, Sheki, and Balakan, and in June, 2013, in Zagatala. Study of the space-time succession of seismic impacts with various magnitudes in each seismic focal zone brings out the following conclusions:

- The epicenters' spatial distribution demonstrates that the above mentioned events are confined to the transverse (northwestern, northeastern, and submeridional strike) disjunctive dislocations. However, epicentral zones are of a General Caucasus strike, dislocated along and to the north of the deep upthrust. Both transverse and longitudinal dislocations are mapped by a complex of seismic and electrical reconnaissance methods. They are characterized as a natural southern extension of the fault-slip type disjunctive zones that outcrop in the mountainous area where structural-substantial complexes of an accretionary zone come to the surface;
- Focal mechanisms of impacts in the separate groups reveal different, mainly close-to-vertical, planes of fault and fault-slip type movements in the earthquake foci. Only in four cases were strictly upthrust and upthrust-overthrust type movements established;
- Hypocenters of major seismic impacts (M = 4.5–5.7) and the absolute majority of aftershocks are confined to the surface of the pre-Jurassic basement or its depths (up to 20 km);
- Most of the hypocenters were confined to a sloping strip which subsides in the northern azimuths, identified with the zone of Ganikh-Ayrichay-Alat deep overthrust and its flakes;
- In general, the seismic activity of a mentioned period is explained by accumulation of lateral compression stresses and their later discharge in an underthrust articulation line from the Middle Kur and Vandam tectonic zones along the Ganikh-Ayrichay-Alat deep overthrust.

Lateral compression first contributed to the creation of transpressional failures along the displacement planes of various-strike transverse dislocations, and the energy discharge in most granulated and weakened areas was confined to the intersection knots of these dislocations between each other and with the deep overthrust with its northern rear flakes.

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The interpretation of "secular" Caspian Sea level records during the Holocene

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According to paleoreconstructions, the Caspian Sea experienced significant changes during the Holocene. The standard deviation for Caspian Sea level (CSL) variations over that interval is estimated as $\sigma = 1.4$ m. Based on well-established views, they were climate-induced variations. But there are no clear links with the calendar of climatic anomalies, and Earth System Models (in the framework of CMIP3 and CMIP5) do not reproduce the required meteorological changes, particularly those of precipitation and river runoff (Kislov et al., 2014). Moreover, there is no clarity concerning what geophysical factors are responsible for the development of anomalies of centennial to millennial scale. Therefore, the question about the origin of "secular" CSL fluctuations remains open.

Based on general ideas about the laws of temporal dynamics relating to massive inertial objects, observed slow changes of the CSL under the semi-steady climate state of the Holocene can be represented as resulting from the accumulation of small anomalies in the water regime; it appears like a kind of "self-developing" system.

To test this hypothesis, I used the model of the water balance of the Caspian Sea (Frolov, 1985). Additional necessary information (e.g., the Volga River runoff and evaporation rate) was assessed on the basis of observation. Time scale for the sea fluctuations was estimated as $\tau \sim 20$ years. This model is interpreted as stochastic, and from this perspective, it is a Langevin equation that incorporates the action of precipitation and evaporation like random white noise, so that the whole can be thought of as an analogue of Brownian motion (Demchenko and Kislov, 2011). Under these conditions, the Caspian Sea is represented by a system undergoing random walk. It should be emphasized that modeling results are interpreted from the probabilistic point of view, despite the fact that the model is deterministically based on the physical law of conservation of water mass (Frolov, 1985).

The results showed that the CSL fluctuations under steady state conditions are characterized by $\sigma = 1.1$ m, close to the empirical value. During the Holocene, CSL variations remained within the range of 4σ.

Large anomalies in CSL are not prohibited by the theory, but their development requires a correspondingly long time. However, during long periods of time, background climate conditions change, and uniformity of the Brownian process becomes disrupted. The origin of large transgressive/regressive stages can be different. For example, the low stand of the Caspian Sea during the Enotaevkian Regression was determined by a significant reduction in precipitation over the Volga River catchment and by a corresponding reduction in the volume of river runoff (Kislov and Toropov, 2011).

Hence, based on modeling results, I show that the possibility of "self-development" effects is not prohibited by the theory: there need not be any cause for specific level changes or shifts; it is merely the expected behavior of so-called red noise processes and has no “cause” any more than does a sequence of rolls of dice that produces a statistical excess of the value five.

The developed theory allows one to reproduce the statistical properties of Caspian Sea level variations. This method is applicable to any massive closed reservoir. In particular, it can be used for the interpretation and understanding of Black Sea level fluctuations during the period of its isolation from the World Ocean.

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The October 23, 2011 ($M_W = 7.2$) earthquake of Eastern Turkey and tectonic-morphological implications for the region

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Eastern Anatolia is a tectonically active region where the Arabian plate converges northward and collides with the Anatolian plate. This tectonic setting has resulted in active diffuse N-S crustal shortening and thickening, strike-slip faults of varying size and direction, and a volcanism active since the Pliocene (e.g., Dewey et al., 1986; Koçyiğit et al., 2001; Şengör et al., 2003; Keskin et al., 2003). Geodynamic-geodetic studies suggest that the convergence is partially accommodated by distributed deformation along strike-slip faults within Eastern Anatolia and partially by accommodation within the Caucasus thrust front in the north (Jackson, 1992; Sandvol et al., 2003; Reilinger et al., 2006).

Thrusting and crustal shortening was dominant during the earliest stages of the collision. Absence of deep earthquakes (e.g., Türkelli et al., 2003), strike-slip dominant focal mechanisms for the moderate and large earthquakes in the upper crust (e.g., Toksöz et al., 1978; Örgülü et al., 2003) and the lack of active major thrust faults (Dhont and Chorowicz, 2006) do not support the notion of ongoing crustal shortening as a main mechanism for accommodation of the convergence at present. A strong earthquake (October 23, 2011, $M_w = 7.2$) occurred in the accretionary prism sediments of Eastern Turkey overlain by Neogene sediments and volcanics, causing substantial damage in the province of Van. The earthquake was considered on a low-angle blind thrust fault previously undetected, because no apparent surface rupture was observed near the seismological epicenter (e.g., Emre et al., 2011). However, surface rupture has been observed discontinuously for several km north of the city center of Van along NW- and NE-trending segments (e.g., Doğan and Karakaş, 2013), but they are generally attributed to surficial effects in water-saturated alluvial deposits of the region.

The occurrence of the 23 October 2011 Van earthquake is no surprise considering the historical earthquake activity. This could be exemplified by the destructive 1646 and 1715 Van and 1696 and 1976 Çaldıran earthquakes (Utkucu, 2013).

The 2011 Van earthquake is surprising in that the preliminary source mechanism studies and the finite-fault modeling have indicated pure reverse faulting with a minor sinistral slip component (Utkucu, 2013). This is because no such large earthquake with pure reverse faulting has been known for the instrumental period in Eastern Anatolia. Since the occurrence of the 2011 Van earthquake, there is a need to investigate or revise this notion. This presentation reviews the October 23, 2011 earthquake sequence in view of seismological and field evidence, and with regard to its tectonic and morphological consequences for the Lake Van region.

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Cyclonic and anticyclonic activity in the Black Sea – Mediterranean region

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Introduction

One of the main aims of recent investigations is to study climate variability and change, and cyclonic and anticyclonic activity is one of the key indicators of global and regional climate. Improved global reanalyses of data sets are characterized by more detailed spatial resolution, which permits the study of long-term changes in cyclonic and anticyclonic parameters for different regions, including the Mediterranean and Black sea basins.

The goal of the present study is to analyze the typical climate characteristics of cyclone and anticyclone frequency in the Black Sea-Mediterranean region and their changes between 1951–2012.

Data and methodology

The 62–year (1951–2012) data from NCEP–NCAR global reanalysis data sets of daily (four times a day) space fields of 1000 hPa geopotential height at 00, 06, 12, 18 UTC on 2.5°×2.5° grid point were used. The analyzed regions were limited by coordinates 37.5°–50° N, 27.5°–45° E for the Black Sea region, 29°–41° N, 14°–38° E for the eastern Mediterranean, and 35°–47° N, 6° W–8° E for the western Mediterranean region. Frequency of cyclones and anticyclones was estimated using specific methodology described by Bardin (1995). To compare the results of estimations in different regions, the calculated values were scaled to an area of about 10^6 km^2.

Results

The highest frequency of cyclones per unit area ($>0.1\cdot10^{-6}$ km^{-2}) is detected in the eastern Mediterranean in winter and in the Black Sea region in spring, whereas the lowest frequency ($0.012\cdot10^{-6}$ km^{-2}) is in the eastern Mediterranean in summer. Variance in frequency of cyclones in the Black Sea region is approximately two times higher than in the Mediterranean and ranges from 0.02 in summer to 0.043 in winter (Table 1a).

Table 1. Seasonal mean / standard deviation of cyclone frequency and their coefficients of linear trends for the Black Sea and Mediterranean regions.

Region	winter	Spring	summer	Autumn
a) seasonal mean / standard deviation (10^{-6} km^{-2})				
Black Sea	0089 / 0.043	0.101 / 0.051	0.050 / 0.020	0.060 / 0.037
eastern Mediterranean	0.103 / 0.025	0.067 / 0.020	0.012 / 0.006	0.046 / 0.016
western Mediterranean	0.085 / 0.025	0.071 / 0.021	0.053 / 0.013	0.075 / 0.019
b) coefficients of linear trends (10^{-3}/year)				
Black Sea	–1.8****	–2.3****	0.3	–0.8*
eastern Mediterranean	0.6	–0.6*	0	0
western Mediterranean	–0.4	–0.4	0.2	0

* = 80%, ** = 90%, *** = 95%, **** = 99% levels of confidence

Linear trends in the frequency of cyclones in the Black Sea-Mediterranean region are mostly low and insignificant. Negative trends in the frequency of cyclones are significant at the 99% confidence limit in winter and spring in the Black Sea region. Negative trends are significant at the 80% confidence limit in spring in the eastern Mediterranean and in autumn in the Black Sea region (Table 1b).

The absolute maximum of long-time average frequency of anticyclones is observed in the Black Sea region ($0.11 \cdot 10^{-6}$ km^{-2}) and in the western Mediterranean ($0.08 \cdot 10^{-6}$ km^{-2}) in summer, while in the eastern Mediterranean, it is in spring, when it reaches $0.11 \cdot 10^{-6}$ km^{-2}. The highest standard deviations for this parameter between 1951–2012 are fixed in winter for the Black Sea region and in summer for both parts of the Mediterranean region (Table 2a).

Table 2. Seasonal mean / standard deviation for anticyclone frequency and their coefficients of linear trend for the Black Sea and Mediterranean regions.

Region	Winter	Spring	summer	Autumn
a) seasonal mean / standard deviation (10^{-6} km^{-2})				
Black sea	0.088 / 0.041	0.087 / 0.023	0.111 / 0.039	0.096 / 0.03
eastern Mediterranean	0.038 / 0.014	0.111 / 0.022	0.084 / 0.022	0.06 / 0.021
western Mediterranean	0.04 / 0.018	0.054 / 0.016	0.078 / 0.029	0.052 / 0.018
b) coefficients of linear trend (10^{-3}/year)				
Black sea	1.3****	0.2*	–0.9****	0
Eastern Mediterranean	–0.3****	–0.7****	–0.9****	–0.6****
western Mediterranean	0.3***	0	–1****	–0.4****

* = 80%, ** = 90%, *** = 95%, **** = 99% levels of confidence

Positive linear trends in anticyclone frequency are found in winter and spring in the Black Sea region, but negative trends are found in summer. The eastern Mediterranean region is characterized by negative trends in all seasons, while in the western Mediterranean, this parameter is significantly increased in winter and decreased in summer and autumn.

Conclusions

A 62-yr climatological analysis of cyclone and anticyclone frequency in the Black Sea-Mediterranean region leads to the following results.

Both eastern and western Mediterranean regions are characterized by winter maxima in the frequency of cyclones, while the Black Sea region reveals spring maxima. Summer minima in the frequency of cyclones are found over the whole Black Sea-Mediterranean region. Generally, variance in the frequency of cyclones in the Black Sea region is twice as high as in the Mediterranean. Linear trends in the frequency of cyclones in both parts of the Mediterranean are low and do not reach the 85% significance level. In the Black Sea region, linear trends are low but significant in all seasons except summer.

Maximum frequency of anticyclones during 1951–2012 manifests in the Black Sea region and the western Mediterranean in summer, while in the eastern Mediterranean, it manifests in spring. During the analyzed period, the frequency of anticyclones in summer in the Black Sea region was characterized by negative trends, and in winter and spring, by positive ones. While the negative linear trends of this parameter are found in the eastern Mediterranean in all seasons, in the western Mediterranean, positive linear trends are observed in winter and negative linear trends in summer and autumn.

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Use of morphological abnormalities in benthic foraminifera in paleoenvironmental research

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Introduction

Paleoecological research largely uses data from fossils and subfossils to reconstruct ecosystems of the past. It involves the study of fossil organisms and their associated remains (e.g., hard shells) for interpretation of the possible influence of environmental factors on the life cycle of organisms. A close link has been found between environmental stress and morphological abnormalities in foraminiferal tests that was first described by Carpenter (1856) and then by Cushman (1933). Most of the available data on deformities was summarized by Boltovskoy and Wright (1976), Haynes (1981), and Boltovskoy et al. (1991), who noted that deformities may be attributed to mechanical damage or environmental stress but concluded that there is no consensus as to the underlying causes of most deformities. In recent years, reports of deformities linked to various kinds of marine pollution have become increasingly more common (Alve, 1991; Yanko et al., 1998, 1999).

The main goal of this paper is to provide insight into morphological abnormalities in foraminiferal tests as a useful tool for paleoenvironmental research in contaminated areas of marine basins (using as an example the northwestern shelf of the Black Sea).

Methodology

Foraminifera were studied using methods described in Yanko and Troitskaya (1987) and Yanko et al. (1998). Obtained results were correlated with environmental parameters and litho-geochemical properties of bottom sediments. Protocol for foraminiferal analysis included sampling, wet sieving of sediment samples through a 63 μm sieve, staining with Rose Bengal, taxonomic identification, morphological analysis under binocular microscope and SEM, biomineralogical research, and mathematical treatment of results. Deformed tests were calculated in order to determine their frequencies in the total population per station. The main types of morphological deformations were described, classified, attributed to environmental parameters using correlation analysis, and compared with a background study performed by Yanko (1975) as well as with the reference collections of foraminifera stored at the Paleontological Museum of Odessa I.I. Mechnikov National University.

Study area

The area of research is located between the Danube delta and the Dnieper-Bug estuary in the NW corner of the Black Sea. It consists of three areas: the Dniester area (#981), the Danube area (#982), and the area near Zmeinyi Island (#993). Sampling was performed in May of 1998 and September of 1999 using the Ukrainian R/Vs *"Argon"* and *"Sprut*,*"* respectively (Fig. 1).

Results

Area #981 is characterized by high frequencies of abnormal tests in 10 species with maximum frequency at station 981-05. The sediments of this station contain the highest concentrations of liquid hydrocarbons (0.32%) in the area.

Area #982 is characterized by high frequencies of abnormal tests in six different types from four (St. 982-263) or seven (St. 982-378) species. The most common deformities were noticed in the dominant species *Ammonia tepida* (Cushman), *Canalifera parkerae* (Yanko), *Elphidium ponticum* Dolgopolskaja et Pauli, and *Porosononion martkobi* Bogdanowich. The highest frequency of abnormal tests was present at St. 982-263 (Kravchuk, 2002).

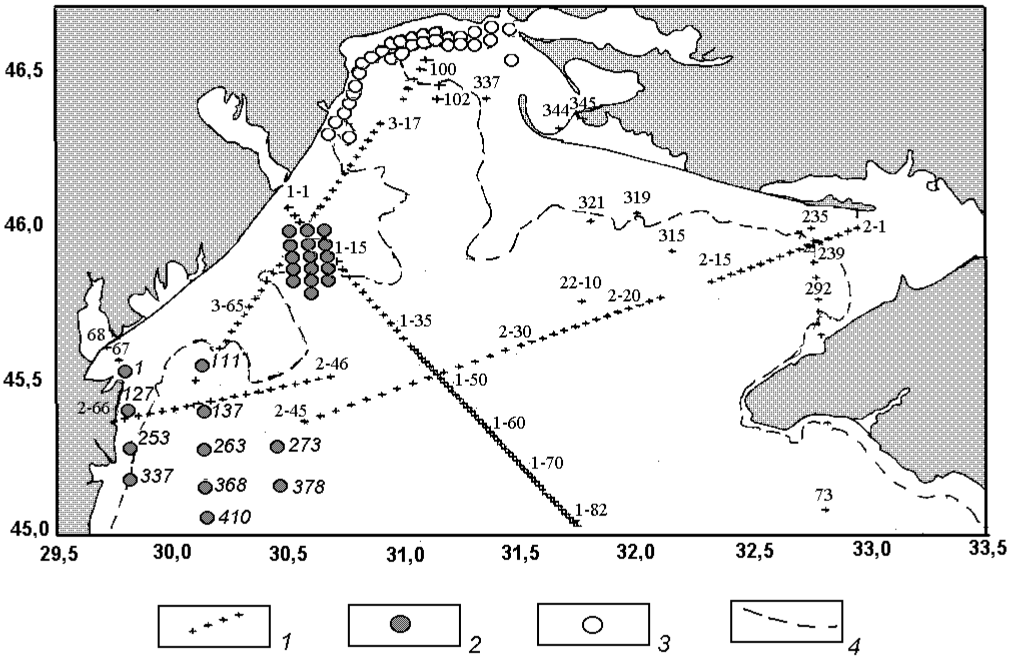

Figure 1. Schematic map of the sampling stations: 1 - transects of stations studied by Yanko (1975), 2, 3 - sampling stations studied by the author from areas (2) #981 and #982 and (3) #993, 4–20 m isobath.

Morphological deformities in tests of the dominant species are represented by nine types: a deviation from the normal type and size of the chambers, the presence of underdeveloped chambers, disturbance in the chamber's coiling, development of additional chambers, lack of sculpture, tumors (teratomas), erosion, and twinning as in "Siamese twins." All these types of deformity can be found in *Ammonia tepida* (Plate 1).

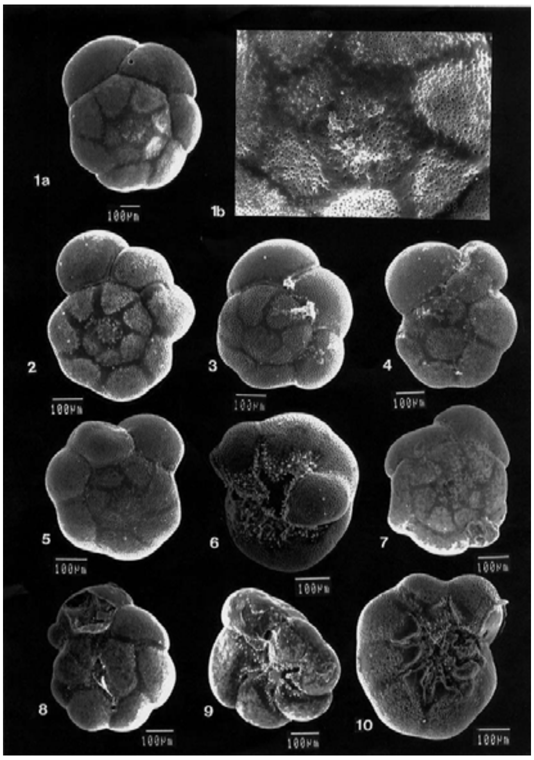

Plate 1. Examples of morphological deformations in tests of A. tepida, NW Black Sea shelf.

Conclusions

Nine types of morphological deformity are described in ten species of benthic foraminifera. They are linked to environmental factors and can be used as proxies for paleoenvironmental reconstructions. There is a clear correlation between degree of contamination of bottom sediments and frequencies and types of morphological deformities of foraminiferal tests that is most probably related to damage sustained by the foraminiferal cytoskeleton by contaminants or some natural factors (e.g., decrease in salinity).

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New data on the Pleistocene stratigraphy of Western Cheleken

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Keywords: Caspian Sea, Khvalynian transgression, Pleistocene, malacofauna, radiocarbon dating, Cheleken, Turkmenistan

Introduction

The Cheleken Peninsula is located in the coastal part of the western lowlands of Turkmenistan. This brachyanticlinal fold was formed in the nucleus by Neogene-aged rocks on the periphery of a variety of Pleistocene sediments, broken by faults at the sides and with active modern manifestations of mud volcanism and high tectonic activity (Leontiev et al., 1977).

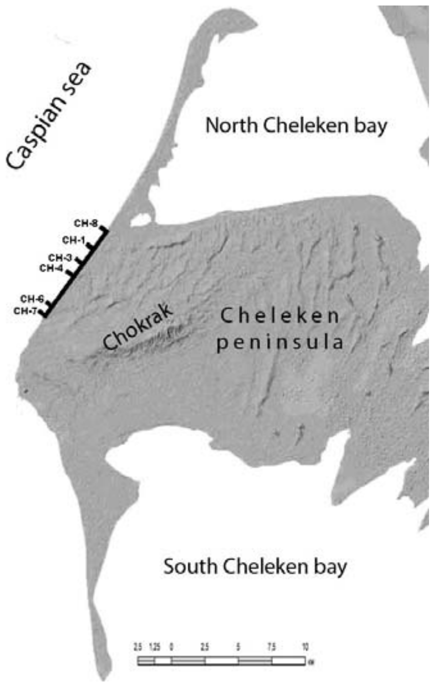

Fig. 1. The Cheleken peninsula and location of the main sections.

Geomorphologically, the peninsula comprises three sections. Located in the central part are the Chokrak hills, with elevations up to 92 m; here, red-colored strata (Akchagylian and Absheronian sediments) are exposed to form badlands terrain. The Chokrak hills are surrounded by Khvalynian sandy terraces, the surfaces of which are largely worked by eolian processes (Kurbanov, 2010). Two large meridian-oriented sand bars are elongated north to south along the peninsula.

The marine Pleistocene of Cheleken, as well as the entire Caspian coast of Turkmenistan, have been poorly studied. The first investigations were conducted by V.N. Veber and K.P. Kalitskiy (1911) more than a hundred years ago. The last major work by P.V. Fedorov (Fedorov, 1946). and L.A. Nevesskaya (Nevesskaya, 1958) appeared more than fifty years ago. Subsequently in Cheleken, the authors conducted a detailed study of key sections and obtained new material. The first studies consisted of an analysis of Caspian marine mollusks (as the basis for biostratigraphic subdivision) and radiocarbon analysis. The studies applied geomorphology and lithofacies methods.

Results

In 2008–2013. we systemically studied key sections in western Cheleken, and with a high degree of reliability, we have defined all subsections of the Pleistocene in the Caspian region (Svitoch and Yanina, 1997). Among them were the faunistically-characterized Urundzhik, Lower Khvalynian, Upper Khvalynian, and Neocaspian horizons. Complexes of Caspian mollusks are the basis of the stratification of marine sediments. L.A. Nevesskaya (Nevesskaya, 1958) and P.V. Fedorov (Fedorov, 1957) studied the mollusks of the Turkmen coast of the Caspian Sea in great detail. Our studies are a logical continuation of their work in that they have been conducted within a specific section of West Cheleken, and they characterize features of the structure and stratification of marine sediments on the Cheleken peninsula. Among the reference sections, we managed to identify 8 genera and 13 species of bivalves and gastropods comprising 4 complexes. 1. The *Cerastoderma glaucum* complex, section CH-8 (Fig. 1) characterizes Neocaspian deposits and is represented by numerous small *Cerastoderma glaucum* shells mixed with rare *Dreissena polymorpha*, *Dreissena distinkta*, *Adacna vitrea*, *Theodoxus*, and single kressoid *Didacna*. 2. Complex *Didacna praetrigonoides*-*Didacna cristata*, section CH-1, CH-3, and 7-CH (Fig. 1). This *Didacna* complex belongs to the group of trigonoidal Khvalynian *Didacnas*; these are big thick shells of a regular triangular shape, with a high crown and steep rear field and differing keel sharpness. The complex is mainly represented by small gastropods: *Micromelania caspia* and *Theodoxus*, many *Dreissena celekenica* and *Dreissena polymorpha*, and typically *Corbicula fluminalis*. 3. The *Didacna umbanata* complex, section CH-6 (Fig. 1). Shells often occur in pairs of wings, and they are characterized by small size, strong convexity, large central keel, and rounded crown. With its small size, we found shells that differed significantly (by two or more times) from those forms of *Didacna umbanata* selected and shown by A.G. Eberzin (Nevesskaya, 1958). In addition to the form of the complex are rare small *Didacnas* and *Dreissena caspia* and *Micromelania caspia*. 4. The *Didacna eulachia* complex, section CH-7, (Fig. 1), as well as the previous set, is mono-dominant and is represented by large, massive, bulging center-crown shells of *Didacna eulachia* (Fig. 2), with a rare mix of *Dreissena polymorpha*, *Dreissena distinkta*, and *Micromelania caspia*. The age of the host rocks is uniquely defined as Urundzhik.

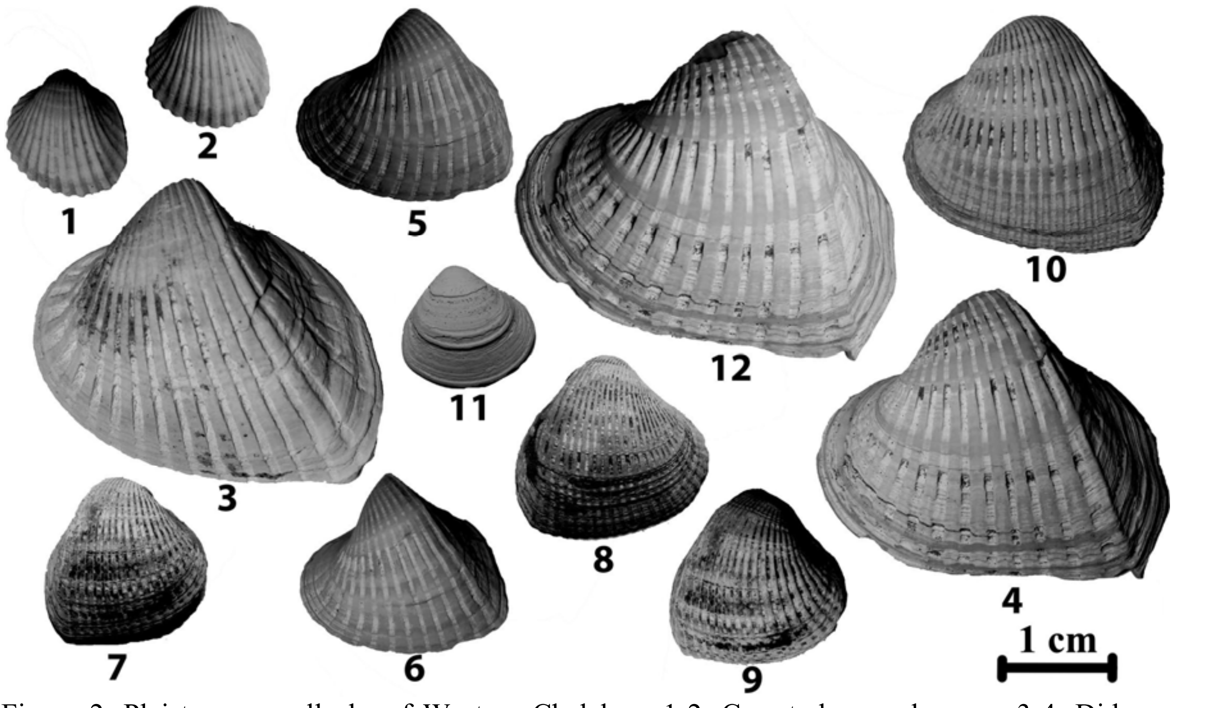

Figure 2. Pleistocene mollusks of Western Cheleken: 1-2. Cerastoderma glaucum; 3-4. Didacna praetrigonoides; 5-6. Didacna cristata; 7-10. Didacna umbanata; 11. Corbicula fluminalis; 12. Didacna eulachia.

To date, there have been no radiocarbon dates for the Cheleken Pleistocene. In 2013, the Laboratory of Paleogeography and Geochronology of the Quaternary SPSU obtained two radiocarbon dates on shells of *Didacna praetrigonoidas* (section CH-1 in Fig. 1) and *Didacna umbanata* (section CH-6), respectively: 11,830 ± 160 BP, cal 13,750 ± 170 (DR-7111) and 13,870 ± 230 BP cal 17,260 ± 160 (UL 7113), demonstrating a Lower Khvalynian age for the deposits.

The Pleistocene section of West Cheleken is characterized by a plurality of different depth intervals, sometimes accompanied by washouts. Varying degrees of washout intervals were observed between almost all stratigraphic layers, the largest of which is set in the context of CH-7 (Fig. 1), where the foot of the Khvalynian sands rests on Urundzhik clays.

Conclusions

Materials from systematic studies of reference sections along the northwestern coast of Cheleken, a detailed analysis of the faunal collections of fossil malacofauna and its radiocarbon dating have provided new data on the structure of specific sections of the still under-researched area of the Caspian coast. 1. In the general section of Pleistocene marine fauna, four layers make up its stratigraphic framework. 2. Identified and described faunal complexes of mollusks distinguish Urundzhik, Lower Khvalynian, Upper Khvalynian, and Novocaspian deposits. 3. For the first time, a radiocarbon age from a Western Cheleken section assigned a Khvalynian age to the deposits.

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Holocene Black Sea level fluctuations, global climatic change and human activity in Georgia (Caucasus)

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Key words: Holocene marine sediments; archaeological sites; palynology; human impact;

Introduction

Holocene sediments of the Black Sea in Georgia have been studied intensively for a long time.The main goal of the investigation was to compare the revealed climate changes with sea-level fluctuations over the last 10,000 years. Beside this, another objective of our investigation is to establish interconnections between the character of human activity and climate during the entire Holocene. Climate changes and, in particular, coolings were of critical importance in the development and evolution of living organisms, including humans. However, during the Holocene, climate warmings rather than coolings have had special impact on the development of society and especially in the appearance of new cultures. The aforesaid tendencies were typical for the Plio-Pleistocene and have been revealed by complex investigation using many methods of interdisciplinary sciences. Palynological material from archaeological sites can help to reconstruct cultural landscapes and human activity during the period in question (Behre 1981; Berglund 1991, 2003).

Material and methods

The database for marine and littoral-marine sediments consists of 26 bore pits drilled in the coastal area (continental shelf) of the Black Sea. Palynologically, the Black Sea shelf and lagoon sediments studied comprise mostly fine grained sands, silt and clay (Kvavadze and Bilashvili 2007, 2008a,b, 2009, 2010a,b,c). The depth of Holocene sediments in the region varies from 17 to 27.8 m. In order to establish the effect of human activity on the environment, palynological investigation of a substantial bulk of archaeological material was carried out (Kvavadze and Rukhadze, 1989). In the western part of Georgia, two sites of the Neolithic period were studied. In eastern Georgia, pollen from early agricultural settlements of the Bronze Age and from the Ancient to the Middle Ages were also studied palynologically (Kvavadze and Licheli, 2009; Kvavadze and Shatberashvili, 2010). The results of this investigation were compared with the data from marine sediments. The analysis and synthesis of all pollen material allowed us to obtain rather interesting results.

Results

The obtained pollen monitoring results allow more accurate reconstructions of paleoecological events in the Holocene of Georgia. Marine sediments provide unique and informative evidence to establish regional and multi-regional processes of environmental fluctuation caused by global climate changes. Their sediment accumulation is not interrupted, and therefore, the dynamics of all events and their trends are recorded completely.

For instance, during climate warmings, the area of low-mountain deciduous woods widened. The upper tree level shifted to higher elevations. However, during periods of cooling, on the contrary, the area of high-mountain coniferous woods extended, and deciduous species became less important. The tree level shifted downward. This process is clearly seen in all pollen diagrams of marine sediments and cultural layers of archaeological sites. But it is difficult to trace local processes in the development of landscapes within the spectra of marine sediments, since all bore pits drilled into the marine shelf are far away from the continent. This deficit can be remedied by studying archaeological material in which the type of landscape where humans lived is clearly seen. Pollen spectra of cultural layers from ancient human settlements reflect the character of anthropogenic activity and the occurrence of new cultures. Recently, cultural layers from the sites of ancient settlements at Vani, Eshera, Nokalakevi and Pichvnari have been studied by palynological and paleoethnobotanic methods (Rukhadze et al.,1988; Bokeria et al., 2009; Kvavadze et al., 2010a).

Conclusion

For the last 10 thousand years, five large regressive and five transgressive phases have been observed in development of the Black Sea due to global climatic changes. Against the background of large transgressive-regressive phases, smaller fluctuations can be singled out.

The occurrence and development of the Neolithic culture in Georgia coincides with climate improvement after the phase of the Würm glacial period and Younger Dryas. In Colchis, the early agricultural culture reached its fullest florescence in the second half of the Neolithic, i.e., in the 7th–8th millennia BC. Cattle-breeding and beekeeping were well developed. By that time, there was already weaving-machine (loom, bench) textile production in Georgia. At this stage, humans could not yet have a harmful impact on the environment.

The Eneolithic period was accompanied by the initial stage of the Atlantic warming during which agriculture in western and eastern Georgia became more intensive compared to the Neolithic.

The Bronze Age was a critical period in the development of culture at all its stages. Metallurgy appeared and developed radically, changing the structure of economics, facilitating further the development of culture and society. Humans began to cultivate both lowlands and mountains. Agriculture also penetrated into the high-mountain regions. Foreign and domestic trade intensively developed. At that time, Georgia had relations with India from which cotton fabric was imported. The first “population explosion” recorded in the Late Bronze and early Iron Ages was undoubtedly caused by the improved conditions of life and natural conditions. Precisely from that time, the first and strongest destruction of forest is observed. Substantial deforestation in Georgia has been observed since the Bronze Age, which might have been caused by development of metallurgy and agriculture.

The next stage in the development of culture took place during the Antique time that was based on the Late Bronze civilization. In the 4th century BC, covering the whole territory of west Georgia, the ancient Georgian state called Colchis (Egrissi) kingdom was formed. The rich archaeological material in west Georgia shows a high level of economic, political, and social development that could not have been reached without state organization. The appearance of a state silver coin “kolkhidka” in all of Colchis by the end of the 6th century indicates the existence of a strong power even prior to the Greek invasion. Here, in the early ancient period, the second “population explosion” after the Late Bronze Age is recorded. The Middle Ages are also distinguished by substantial shifts in the development of culture and climatic conditions. Warming, the maximum of which occurred in the 9th–11th centuries favored intensification of agriculture and other branches of the economy. Georgia became a strong and leading state. At that time, another “population explosion” is observed. Anthropogenic impact on the environment became more significant. Woody vegetation was destroyed not only in the lowland, but also in the mountains.

For the last three centuries, the various landscapes have undergone the strongest anthropogenic pressure. In the Colchis lowland, almost complete destruction of forests took place. Bog reclamation, besides unsystematic felling, contributed to the degradation of woody vegetation. In the coastal zone, erosion activity of sea and river waters increased, which was also caused by the rise of sea level over the last three centuries.

In the mountainous part of Ajaria and Imereti, after the felling of trees, landslips and cloudburst floods became so active that the local population had to migrate to flatter and safer locations. Similar processes also took place in Abkhazia, especially in the zone of Akhali-Ateni and Gudauta.

The tree level shifted downward. In the high mountains, grain-growing, gardening, vine-growing, and beekeeping developed. During climate warmings, the area of low-mountain deciduous woods widened. The upper tree level shifted to higher levels. However, during the periods of cooling, the area of high-mountain coniferous forests extended, and deciduous species became less important. During the Holocene, transgressive phases with warm climatic conditions lasted longer than the regressive phases.

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Landscape evolution of the Kolkheti lowlands during the last five millennia—a geoarchaeological project on the Black Sea coast of Georgia

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Keywords: Rioni, paleogeography, luminescence dating

Introduction

In 2013, a research project dealing with the paleogeography of the Kolkheti lowland on the Black Sea coast was started. Studies have focused on (i) the reconstruction of the landscape of the Rioni delta plain and several other coastal areas in western Georgia by means of geoscientific methods, and (ii) deciphering the human impact on landscape evolution and human adaptation to the changing landscapes. Special attention is given to the environs of former settlement and harbor sites.

Methodology and goals

Essential to achieving the above goals were vibracorings in different geoarchives. To establish a chronostratigraphy, different dating methods were applied: ^{14}C ages of organic material and OSL age estimates from the beach barrier system north of Poti. With palynological analyses of the peat bogs and lake sediments, the vegetation history will be reconstructed (cf. Connor et al., 2007; de Klerk et al., 2009). Due to Georgia's long agricultural and mining history, signals of early agricultural and mining activities can be traced in the sediments (XRF scans, ICP-MS; cf. Narimanidze and Brückner, 1999). Moreover, possible sites that might represent the as yet undiscovered ancient city of Phasis known from historical sources will be identified by geoscientific methods. Another aspect is the reconstruction of the sea-level curve for the Georgian coastline, which will lead to a better understanding of coastal evolution. These results are embedded within the greater context of the discussion concerning the Holocene fluctuations of the Black Sea (see e.g., Brückner et al., 2010; Fouache et al., 2012).

First results

During two field campaigns, drillings were carried out in the research area focusing on the Rioni delta, the swamp areas between Poti and Kulevi, and the shores of Lake Paliastomi. Based on geochemical analyses, a remarkable landscape change was identified that occurred during the last millennia. For the southern shores of Lake Paliastomi, the interaction of shallow marine, fluvial, and lacustrine sedimentation is well documented. First, ^{14}C ages allow for a chronostratigraphy of the environmental changes near the outlet of the river Supsa.

In addition, four samples were taken for OSL dating from two sites of the extended sand barrier system north of Poti. Ages were obtained for the contact zone between the barrier sediments and the overlying dunes, which evolved on this barrier after it had risen above sea level. The dunes can be dated back to around 1500 BP; thus, the sand barrier that cuts off a lagoon from the Black Sea must have evolved earlier. The area behind the barrier is being studied microfaunistically and geochemically in order to decipher the change from an open lagoon to the recent swamps.

Furthermore, the first XRF scans have revealed changes in heavy metal ion concentrations, which can be linked to (historic) mining in the hinterland.

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The experience of applying paleoclimate scenarios to estimate future hydrological regimes (the Caspian Sea as a case study)

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Keywords: Global warming, the Holocene, air temperature, precipitation, runoff, heat-water balance model

Introduction

Prediction of changes in the hydrological cycle under climate change forcing is an important task of hydrology and physical climatology. Two independent modes are now used to solve this problem: modeling by GSMs and testing empirical data.

The urgency of this problem has been elevated for several decades, thereby accounting for the many relevant publications on the subject. The current study of water resources in the Mediterranean region and its sub-areas can be divided into two directions: (1) the study of the current, modern state and (2) forecast of water balance and sea level in the future. Most research dealing with observational data has constructed stochastic models and trends, revealing the relationships between moisture, river runoff, and precipitation on the basis of the analysis of modern fluctuations (Perevedensev et al., 1999; Shiklomanov and Georgievsky, 2002), atmospheric circulation processes (Meshcherskaya, 2002), and modeling of prospective future water balance (Shiklomanov and Georgievsky, 2002; Frolov, 2003). These cross-disciplinary studies have demonstrated not only the application of various approaches to decision-making on this problem, but also the necessity of such diverse strategies. The main cause is significant uncertainty about water resource forecasts for large areas, and in particular, changes in precipitation and runoff. In spite of the progress made with Global Climate Models, scientists are looking for alternative sources of information.

Over the last decades, in addition to progress in understanding global temperature rise, progress has also been made in paleoclimate reconstructions. The Mediterranean region is interesting from a hydrological point of view, and particularly the Caspian Sea basin because of its status as a closed lake.

The Caspian region is the outstanding indicator of moisture conditions

Caspian Sea history consists of transgressions and regressions resulting from fluctuations in its water resources and water balance components during the past epochs. The most productive tactic is to "read" the "paleoenvironmental signature." Investigation of this "signature" allows us to get reliable data about climate and environment in the past (cold and warm intervals). In this region, paleogeography, paleoenvironment, and climate have been reconstructed for both warm and cold periods.

The Caspian region is one of the outstanding indicators of moisture conditions over a vast area in the present time and also in the past. Relatively recently, it was assumed that a hot and arid climate, typical of the modern Caspian area, was typical throughout the greater part of the Pleistocene and the Holocene. However, abundant archaeological data have testified to the fact that in the mid-Holocene between 9.0 and 4.5 ka BP (the Early Boreal warming and climatic optimum), the Central Asian deserts, including the regions of the Ust'yurt, the Mangyshlak, the Kara-Kum, and the Kizil-Kum, were inhabited by ancient humans. The last and most considerable lake episode in this region is dated at 9–5 ka BP. This episode is associated with the development of a soil horizon and steppe and semi-steppe vegetation where annual precipitation was 1.5–2 times above that of the present.

Analysis of the paleobotanical, paleohydrological, and archaeological materials allows the assumption that between 9–5 ka BP, when summer air temperatures in the high latitudes were 2–3°C above modern levels, in the regions adjacent to the Caspian sea (Ust'urt, Mangyshlak, and Central Asia), steppe and savannah-like landscapes predominated in the place of the modern semi-deserts and deserts. The last pluvial episode in these regions is dated at the time of "the Medieval warm epoch." In the palynological spectra of layers dated between the 6th–12th centuries, about 38% cereal pollen and a small amount of arboreal pollen have been found, which seems to be associated with the a forestation of the northern slopes of the Mangystau mountains (Varushchenko et al., 1987).

Paleoclimatic reconstruction as a scenario of future climate

Current climate change appears as global warming, and that is why most paleoclimate reconstructions propose warm periods in the past. The changes in climate are likely to be caused by increasing carbon dioxide concentration in the atmosphere, and future conditions in some features would resemble the Pleistocene and Neogene warm epochs. Two of them correspond to global warming of a small scale (by 1°C and 2°C): the Holocene optimum (6.2–5.3 ka BP) and the Last Interglacial (125 ka BP).

Based on paleoclimatic reconstruction maps of air temperature and annual precipitation (Borzenkova, 1992) to predict scenarios of climate conditions in the 21st century, hydrological cycles have been estimated for the area of the Northern Hemisphere, including river basins and closed and open lakes and sea basins (e.g., the Black and Azov Seas, Caspian Sea). To evaluate the changes in climate and hydrological parameters in step with the progress of global warming, a steady-state hydrological model has been developed (Lemeshko, 1992; Borzenkova and Lemeshko, 2005). The results are presented in maps of annual runoff, evaporation, seasonal moisture content in a 1-meter soil layer, duration of snow cover, and warm period changes, all compared with the progress of global warming for the regions of the Northern Hemisphere. In the next phase of our study, three warm periods have been investigated over the course of the Holocene—the Holocene climatic optimum (6.2–5.3 ka BP), and the warming of the 1930s and 1978–1995—in order to study ranges of sea-level fluctuations.

Conclusion

As a conclusion, it should be noted that paleoclimate reconstructions have good prospects. They could be used as instruments to reconstruct atmospheric circulation in the geological past. The first attempt to use paleoclimate scenarios to predict atmospheric circulation patterns was done in the frame of IGPG 610. An evolved approach will allow us to explain the mechanisms between changes in global temperature and precipitation in different latitudinal zones.

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Reconstructing Caspian Sea level changes and climate from dinocysts and pollen from the Late Pleistocene to the Mid-Holocene

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Keywords: Caspian Sea, sea level, dinocysts, salinity, pollen, vegetation, Holocene, Late Pleistocene

Introduction

Three Late Pleistocene and Holocene sequences from the south (a deep-sea one and a coastal one) and the middle (a deep-sea one) basins of the Caspian Sea (CS) have been studied for their palynological contents at high-resolution in order to reconstruct separately past vegetation (hence climate) and past water salinities (hence water levels) (Leroy et al., 2007, 2013a, b, c, 2014). The aims of this investigation are to obtain further evidence of sea-level changes, vegetation, and climate, and establish the main forcing factors in the Caspian Sea region.

Methodology

The coastal core (27.5 m) was taken by drilling. The marine cores were taken by Kullenberg (10 m) and pilot (1.8 m) corers. Palynology (pollen, dinocysts, and NPPs) was used to reconstruct past environments. Radiocarbon dating was performed to create a chronological framework in order to compare the data from the different sequences. Ages were corrected for the amount of detrital if bulk, but when possible, ages were obtained on shells and on organic matter. Radiocarbon dates were calibrated and reservoir corrections were applied when necessary (except the plant remains) before the age-depth modeling. Each sequence followed a different approach (Leroy et al., 2007, 2013 a, b, and c, 2014). Statistical analyses were applied in order to extract the main common changes objectively.

Results

The Younger Dryas is well marked by a regional aridification of the climate, but sea level remained high and was still part of the Late Pleistocene (Khvalynian) highstand.

The brief Mangyshlak lowstand in the Early Holocene is characterized by brackish waters in the deep sequences and a hiatus in the coastal one. No specific vegetation changes were observed. It is suggested that this water level lowering was due to a starvation of water inflow to the CS in response to hydrographic modifications of the main rivers under a climate that remained very dry at the beginning of the Holocene.

A delayed development of trees after the initial Holocene warming was indicated in the deep-sea cores and occurred not before 8.3 cal ka BP. In the coastal sequence (located at the foot of the Elburz Mountains), trees survived in glacial refugia, and they developed earlier than in the deep-sea sequences at the beginning of the Holocene.

During the Holocene, the freshest waters are inferred from 8.3 to ≤4.0 cal ka BP, linked to a connection of the CS with the Amu Darya, which was fed by the melting of Pamir Mountains glaciers. The Amu Darya flow is positively correlated nowadays with the Indian Summer Monsoon. An overflow to the Black Sea is suggested for that period, although it is not recognized in the Black Sea. A sharp drop of water level is finally reconstructed at c. 3.9 cal ka BP, before the start of the Neocaspian period, close to present-day conditions.

Conclusions

At present, CS levels are mainly forced by summer precipitation on the Volga drainage basin (Arpe et al., 2014). For some previous periods, the drainage basin of the Amu Darya must also be considered in order to understand the CS hydrological budgets. A preliminary comparison between sea levels reconstructed from dinocyst assemblages and from the literature is proposed. Similarities are found with the curve of Svitoch (2013), especially for the high levels from 8.3 to ≤4.0 cal ka BP. A lot of work remains, however, to be done in order to quantify better paleo-salinities from the Caspian dinocysts because of the presence of endemic forms, species, and even genera, only recently recognized.

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New data on the Khvalynian history of the Ergeni bench of Kalmykia

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Keywords: northern Caspian Lowland, chocolate clays, paleogeography, Lower Khvalynian

Intoduction

The Ergeni Upland lies in the northwestern Caspian Lowland. This area divides the Volga River and the Don River basins. During the Khvalynian period, the Ergeni bench was modified by transgression and regression. The structure and development history of the Ergeni bench during the Khvalynian period have been sporadically known in the north as most studies have been investigated in the south. This region (Fig. 1) is the classical area of the maximum Early Khvalynian transgression that deposited marine sediments containing fauna, facies, and chocolate clays.

Figure 1. Map showing the locations of investigated sites in the Gryaznaya, Yalmata, and Arshan'-Zelmen river valleys in the Kalmykia area.

Methods

The investigated area includes the Gryaznaya, Yalmata, and Arshan'-Zelmen river valleys. Generally, the thickness of Khvalynian sediments is about 6–8 m, but a thickness of about 10–20 m may be found in topographic pre-Khvalynian depressions different in origin, outlines, and size (Britsyna, 1954;

Moskvitin, 1962). Field study included comprehensive investigations of the Khvalynian sections. The range of applied methods included: geomorphological, lithologic-facies, and malacological analyses. The altitudes were measured by GPS. Khvalynian sediments were sampled from outcrop walls in Gryaznaya (~28 m a.s.l., 47°56’45.70” N, 44°37’04.71” E), in Yalmata (~34 m a.s.l., 47°52’34.66” N, 44°36’48.97” E), in Arshan’-Zelmen (~32 m a.s.l., 47°35’47.01” N, 44°36’00.60” E), and in the quarry near Tundutovo (~32 m a.s.l., 47°56’59.54” N, 44°37’25.36” E). For local correlation, Early Khvalynian sediments of the Tundutovo section along with their contents of chocolate clays and mollusk fauna have been used as a stratigraphic marker.

First Results

Four sections and their sedimentary environment have been described. Lower Khvalynian layers are found at hypsometric levels of 18 to 30 m. Sea level did not exceed +36 m because of the absence of higher marine terraces. During the Early Khvalynian, this region was characterized by a quiet depositional environment. The Khvalynian deposits in the Tundutovo and Yalmata valleys are dominated by the chocolate clays that occur usually at the center of the sequence. Chocolate clays include sand and silt interbeds with shells of the index species *Didacna protracta*.

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Modern methods of geomorphological mapping and their prospects

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Keywords: GIS, digital elevation models, digital geomorphological mapping, ASTER, SRTM

Geomorphology is the science that investigates how landforms are formed on the Earth. The study of landform evolution and development is a debatable issue today in remote areas with limited field-based glaciological measurements. Geomorphological mapping is a very effective tool in the management of natural resources, and it helps in various types of planning and development activities.

Thematic maps in the earth sciences are an essential tool for the representation, analysis, and visualization of geological processes. Among the large variety of thematic maps, geomorphological maps are particularly useful in understanding natural phenomena associated with human activities.

Geomorphological maps report the erosion and depositional relief landforms, including submarine ones, highlighting the morphographic and morphometric characters and interpreting the endogenous and exogenous morphological processes, in the past or present, that produce and shape the topographic relief. In this kind of map, the chronological sequence is also reported, distinguishing between active and inactive landforms. In addition to its scientific value, geomorphological mapping is the necessary starting point for different studies, such as applied geology and environmental protection investigations for socio-economic improvement. A major problem with geomorphological information is that it is extremely complex to represent due to the huge amount of data.

Historically, geomorphological mapping has been based upon integration of multidisciplinary information from the field, remotely sensed data, and cartographic map products. Regional-scale geomorphology and physiographic analysis and mapping were based upon the interpretation of photography and smaller-scale maps to classify terrain types or features at the regional scale. Detailed geomorphological mapping was based upon surveying and other *in situ* measurements, although detailed large-scale geomorphological maps did not exist for many areas (Bishop et al., 2012). These traditional mapping approaches emphasized qualitative interpretation, as was frequently dictated by the inherent limitations associated with field work, the paucity of digital space-time data, and human *a priori* field/geographic experience and domain knowledge. Consequently, the power of the human visualization system was primarily relied upon, introducing subjectivity and biases with respect to selection of criteria for terrain segmentation and placement of boundaries.

Earth science investigations using geospatial technologies are commonplace. The rapid proliferation of geospatial technologies includes advances in geodesy, photogrammetry, geophysics, computer science, statistics, remote sensing, and geographic information systems (GIS), to mention just a few. Numerous conceptual/theoretical and information technology issues are at the heart of digital geomorphological mapping (DGM) (Bocco et al., 2001). We have new capabilities, but there are also numerous issues in geomorphology that have not been adequately addressed. Therefore, Earth scientists need to be fully aware of current capabilities, as well as the issues and challenges related to geomorphology and GIS science.

Today, Earth scientists are increasingly incorporating quantitative topographic information, spatial analysis, and modeling into their research. GIS-based applications in geomorphology range across the full suite of process domains and associated landforms. Often examined through images or scientific visualizations, more applications are assessing space-time patterns of geomorphic landscapes, multi-scale features, and process domains, scenarios of landscape change, shifts in disturbance regimes, and land degradation associated with natural forces and human factors. Addressing such fundamental geomorphological and place-based questions has included the integration of terrestrial, airborne, and satellite remote sensing technologies.

Global positioning satellite (GPS) technology has been commonly used to describe the geographic location of landscape features and unique patterns, and to integrate diverse data. Increasingly, various methods of artificial intelligence are being used to examine non-linear dynamics and feedback processes that are described within the context of complexity theory. These spatially explicit modeling approaches are being used to explore scenarios of landscape change, alternate futures, and divergent landscape patterns. They can also be used to examine internal and external geomorphic forcing functions that can be highly variable and exist at a multitude of space-time scales.

Such new capabilities represent a substantial evolution in geomorphology compared to traditional mapping. Yet, the traditional approaches of information integration via analytical reasoning, which is the pillar of qualitative interpretation, is poorly represented by statistical metrics and mathematical operators that are so commonly used in DGM. Furthermore, results of quantitative analysis and numerical modeling are dependent upon numerous factors and simplifying assumptions, and they may not be representative of objective measurements obtained in the field (Gustavsson et al., 2006). Consequently, conceptual and practical issues need to be recognized that have the potential for geospatial-technology solutions.

Perhaps the most significant contribution of remote sensing to geomorphology is the use of passive and active sensors to generate surface elevation data commonly referred to as a DEM (digital elevation model). A variety of techniques can be utilized for digital terrain modeling including image photogrammetry, radar or laser altimetry, and interferometric synthetic aperature radar. Photogrammetric applications of satellite imagery, including SPOT and ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data, are commonly used by scientists. In the case of SPOT imagery, alternate view perspectives from multiple satellite passes enable stereoscopic representations, whereas the ASTER system relies upon forward- and back-looking telescopes to characterize topography through a merged characterization. Similarly, radar imagery and specifically SRTM (Shuttle Radar Topographic Mapping Mission) data are widely used for mapping. The SRTM and ASTER mission objectives were specifically designed to produce a global DEM data product to facilitate Earth science mapping projects. These DEMs have resulted in many new developments and the ability to automate landform mapping based upon the use of geomorphometric parameters/indices (Fig. 1).

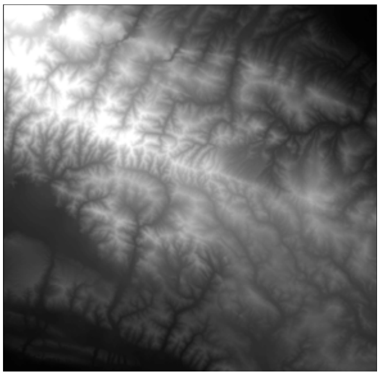
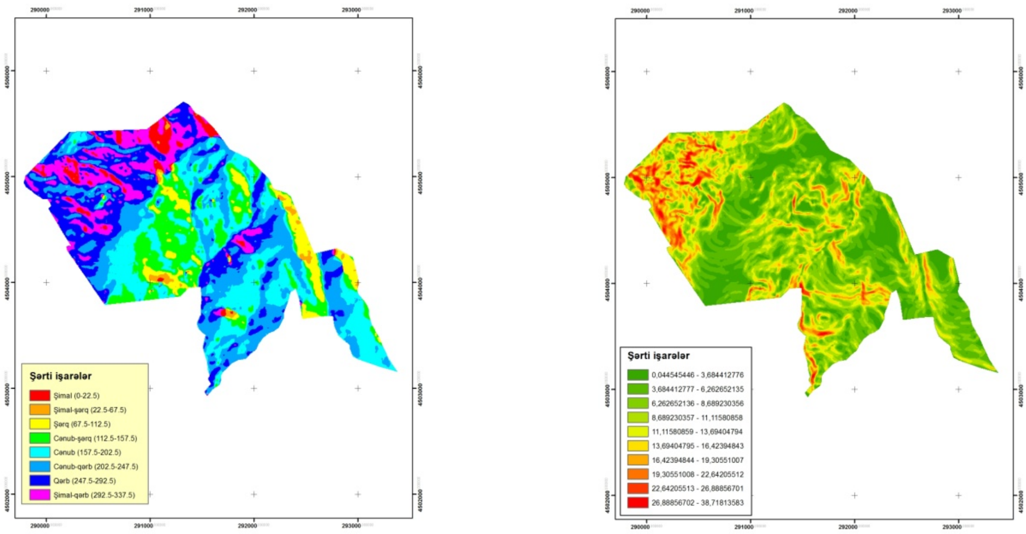


Figure 1. ASTER 1.5 arc-second DEM for the Southeast Caucasus.

More recently, airborne high resolution, light detection and ranging (LiDAR) systems and terrestrial laser scanning systems can generate millions of 3-D point measurements. These “point clouds” must be analyzed and manipulated to ensure accurate interpolation to generate a bare-Earth altitude field. LiDAR high-resolution DEMs permit more accurate geomorphometric characterization of the surface that potentially permits greater accuracy in mapping. These data allow developments in geomorphometry to be exploited, whereas the same techniques may not be as useful given a coarser DEM measurement scale. For example, DEMs of Difference (DoD) are emerging as a form of change detection suitable for examining spatial patterns of geomorphic dynamics and volumetric analysis, but the availability of high resolution, geo-referenced elevation grids is critical.

Geomorphometry is the science of the quantification and analysis of the land surface. It is fundamental to quantitative geomorphology, and is considered a discipline. In general, geomorphometry addresses issues of: (1) sampling attributes of land surfaces; (2) geodesy, digital terrain modeling, and the generation of DEMs; (3) DEM error assessment and preprocessing; (4) generation of land-surface parameters, indices, and objects; and (5) geomorphic information production and problem-solving using parameters and objects. Each aspect of geomorphometry represents a research subdiscipline and contributes significantly towards the development of software tools and geospatial technology (Fig. 2). Its importance in geomorphology is expected to play an increasing role as new and advanced forms of spatio-temporal data become available.



a b

Figure 2. Morphometric maps of Muganli region, Azerbaijan: a) aspect; b) slope.

Geomorphological maps are needed at a variety of scales because surface materials and topography constrain and govern numerous chemical, biological, meteorological, and lithospheric processes. Numerous multi-scale topographic effects influence forcing factors and environmental change. Consequently, geomorphological maps are essential for assessing and managing natural resources and promoting sustainability. Historically, such information was predominately generated via the power of human visualization, using knowledge and analytical reasoning. This permitted great flexibility in integrating multiple information themes. To date, human interpretation still represents the most sophisticated approach for producing complex geomorphological maps at multiple scales, although the issues of subjectivity, reproducibility, and validity remain. Furthermore, the increasing volume of data and the need for sophisticated analysis collectively require computational efficiency and formalization with respect to information extraction. In many respects, the ongoing evolution of geospatial technologies for mapping represents an attempt to automate and simulate human-interpretation capabilities.

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Water factor impact on the contamination and degradation of the Absheron peninsula's soils

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Based upon levels of anthropogenic impact on the environment, the Absheron peninsula must take an exceptionally high position worldwide. Oil production and refining, chemical and metallurgical industry, and agriculture are developed intensively on the peninsula. At the same time, the increasing dynamics of urbanization within the peninsular territory are apparent: in 2012, about 3.5 million people lived here, and at present, over 31 m^3/sec of water resources are transferred to Absheron from other regions of the republic for the population's water supply and production facilities.

The depreciation, and, in some cases, the absence of sewer systems for waste water drainage, the specific hydrogeological conditions, and the irrational water economy activities were the reason for the sudden rise in groundwater level, and, as a consequence, the underflooding, flooding, and swamping of substantial areas of the peninsula. On the Absheron peninsula, groundwater levels rose in the range of 3 to 10–15 m and more. The main factors behind the groundwater level increase in that period were losses from irrigation channels and irrigated areas as well as leakages from underground conduits (water pipes and sewage systems). It has been revealed that areas with occurrence depths up to 3 m from the surface, i.e., the underflooded territories, had increased by 102.5 km^2, and the areas with groundwater level occurrences at 3 m to 5 m were approximately 144.2 km^2.

At the same time, it is known that the hydrologic environment is the active accumulator and distributor of various contaminants that are widely developed within the peninsula. These are waste oil water, sewage from plants and factories, waste water from cities and settlements, pesticides from the irrigated farmlands, etc. The rise in groundwater level has provoked the development of exogenous processes, and as a result, subsidences, landslides, and worsening of the civil-geological conditions of the peninsula have been observed. The intensive anthropogenic load upon the subsoil hydrosphere has disrupted environmental conditions of the Absheron peninsula and the lands in particular. Two independent processes of contamination are distinguished within the peninsula: the direct contamination of the natural and anthropogenic non-economic aquifers and the mediate contamination of soils and grounds with ground- and surface waters. But the same sources of contamination impact the waters. These sources are: oil production, industrial wastes, rural industry, and sewage water from the urbanized territories. It is necessary to mention that the development of the oil, gas, and gas-condensate fields corresponds to the growth of a number of environment-intensive industries, and their influence upon hydrogeological and geo-environmental conditions is notable. The hydrodynamic and hydrochemical parameters of the groundwater of the upper lithosphere in the zone of intensive water exchange are indirectly exposed to impacts, although they do not have direct hydrodynamic connections with oil reservoirs (oil-bearing layers). For example, about 250–300 m^3 of drilling mud was ejected at the surface in the process of drilling oil wells with depths of 2500–3000 m. A number of groundwater contaminants with high migration ability are present in these drilling muds.

Seawater, profusely used for injection into the reservoir and other technical needs as well as the formation waters produced in fields along with oil are also sources of contamination for soils, rocks in the zones of aeration, and groundwater of the peninsula. Salt field waters are produced along with oil and discharged into the nearest depressions. Here, some of the water has formed artificial lakes; other water has leaked into the ground or evaporated and brought about swamping over a substantial area. In the fields, there are primitive ditches for waste water removal. Flows from small field ditches enter the main canals and merge with the sea. For many years, these ditches had been the sources of contamination for the peninsula's underground hydrosphere.

From the above-mentioned characteristics, it follows that highly-mineralized field waters directly enter the ground horizons through the canals, which are operated without waterproofing. The present factors greatly influence the ameliorative state of the lands, mainly within the Bina-Govsan trough. Farm lands, gardens, and vineyards located near these ditches suffered from the salinity. It is also necessary to mention that within the Bina-Govsan trough, the freshwater reserves form. These reserves are considerable for the Absheron peninsula and are suitable for different purposes. But the above-mentioned contaminants impair their quality and diminish their safe uses. According to radiometric investigations, a stressed radiological state can be observed within the territories of many chemical and petrochemical enterprises and oil fields. For many years of oil field operation, and according to the radionuclide content in soils, the situation is such that the soils found within these oil fields must be reclaimed. As a rule, the anthropogenic groundwater is distinguished by increased negative impact upon the land.

The issue of industrial waste utilization is a crucial problem for the peninsula. Soils, the ground surface, and groundwater, as well as the air are intensively contaminated by the unused masses of wastes coming into the dumps and storages. Within the peninsula, just the waste from construction materials production makes up over 400 million m^3. About 97 thousand tons of solid waste are generated annually by industrial enterprises. The industrial waste from metallurgical, petrochemical, and chemical production, and from electrical power plants, are considerably toxic. Hundreds of thousands of tons of toxic waste remain in places of uncontrolled storage, waste deposits, unequipped sludge tanks, pits, and polygons. There are no centralized polygons to bury these toxic unused wastes from industrial enterprises.

The presence of increased amounts of some contaminants of rural origin is observed in soils, rocks within zones of aeration, and groundwater. A higher content of nitrates is observed in the groundwater in local areas as a result of fluviraption of the mineral and organic fertilizers. In series mainly expressed by sandy, sabulous rocks as well as in areas where the thickness of zones of aeration is not great, the groundwater is subjected to the greatest nitrate contamination. A strong nitrate contamination is specifically observed in greenhouses where carnations are cultivated. Sometimes, soils removed from greenhouses and intended for waste deposits, in combination with other chemical elements and compounds, are toxic due to high nitrate concentrations.

The absence of centralized polygons to bury these toxic unused wastes from industrial enterprises as well as the above-mentioned problems affect the environmental security of the Absheron peninsula negatively and bring about soil degradation.

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Small mammal faunas from deposits of the Chaudian transgression

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Keywords: evolution, species composition, stratigraphy, correlation

Introduction

The evolutionary stages of Early to Middle Pleistocene small mammals have been widely discussed in the scientific literature. The interrelation of these stages with the geological deposits, paleomagnetic data, and other paleontological materials is the basis for correlating natural events during this interval. These data reveal the speed of evolutionary changes among the phylogenetic linages of the small mammal indicators, mostly the Arvicolinae. Some of the small mammal localities have been found in liman-marine deposits of different ages, which thereby permits straight correlations between marine transgressions and the natural events on the continent.

Small mammal localities

Several Eastern European small mammal localities were found in deposits of the Chaudian transgression correlated with the beginning of the Brunhes paleomagnetic epoch as well as the beginning of the Middle Pleistocene. These data were obtained during paleomagnetic investigations of the Chaudian deposits of the Chauda key succession (Zubakov et al., 1975).

The locality near the **Priazovskoe** settlement (Taman Peninsula, 36° 55’ E, ~ 45° 25’ N) was discovered in the liman deposits of the Chaudian terrace exposed in the quarry.

The small mammal fauna include *Spermophilus* sp., *Mimomys pusillus*, *M. savini*, *Lagurodon arankae*, *Microtus (Stenocranius) hintoni*, and *M.* ex gr. *oeconomus* (Markova, 2002). These fauna are close to those of Petropavlovka and Karai-Dubina—which are correlated with the very end of the Matuyama paleomagnetic epoch (Markova, 2007) judging from the evolutionary level of *Mimomys*, *Lagurodon*, and *Microtus*. The first appearance of the new taxa (*M.* ex gr. *oeconomus*) is the most characteristic for these faunas. However, the Priazovskoe locality is correlated with the time of the Chaudian transgression, which is related to a later time: the beginning of the Brunhes epoch. So, the faunas of this evolutionary level existed not only during the end of the Matuyama epoch but during the beginning of the Brunhes epoch also.

The **Litvin** locality of small mammals is located at Krasnodar Krai, Taman Peninsula, Litvin Cape (36° 46’ 12” E, 45° 26’ 6” N). The fossiliferous layer was discovered in Chaudian deposits, and so it is correlated with the beginning of the Brunhes paleomagnetic epoch. The remains of *Ochotona* sp., *Allactaga* sp., *Mimomus savini*, *Borsodia fejervaryi*, *Prolagurus pannonicus*, *Eolagurus simplicidens gromovi*, *Allophaiomys pliocaenicus nutiensis*, *Microtus (Stenocranius) hintoni*, and *Microtus arvalinus* have been found at this locality (Markova, 1998; 2007; Markova and Kozharinov, 1998).

The **Nagornoe 1** locality is also related to the Chaudian liman deposits. It is situated in Ukraine, on the bank of the Kagul liman (VII Danube terrace; ~28° 26’ E, ~45° 32’ N) (Mikhailesku and Markova, 1992). This fauna includes *Mimomys savini*, *Prolagurus pannonicus*, *Allophaiomys pliocaenicus*, *Microtus (Stenocranius) hintoni-gregaloides*, *M. oeconomus*, and others, and it is very close to the faunas of Priazovskoe and Litvin. It is important that the appearance of *Microtus oeconomu*s was also registered here. The liman deposits with small mammal bones also include the rich fauna of brackish-water mollusks: *Didacna* ex gr. *tschaudae*, *D. baericrassa*, and *Dreissena polymorpha*, which dated the deposits to the time of the Early Chaudian transgression and the beginning of the Brunhes epoch (Mikhailesku and Markova, 1992). The position of these faunas in the biostratigraphical scheme is shown on the Fig. 1 (Markova, in press).

Geo-chro-nology		PM	Ma	MIS	Western Europe				Eastern Europe				
					Large mammal complexes	Small mammal complexes	Faunas callibrated by PM	Localities	Large mammal complexes	Small mammal complexes	Faunas callibrated by PM	Localities	First appearance of species
PLEISTOCENE	MIDDLE			17 18	GALERIAN	BIHARIAN	Kärlich F Kärlich C-F	Kärlich F Kärlich C-F West Runton	TIRASPOLIAN	TIRASPOLIAN	Kolkotova Balka	Posevkino Perevoz Suvorovo Ilovaiskii Kordon Bogdanovka Troitsa 1 Kolkotova Balka (fluvial) Uryv 3	*Lagurus transiens*
												Litvin Ilinka 6 Nagornoe 1 Priazovskoe	*Microtus (Stenocranius) gregaloides*
			0,78	19			Trichera Dolina (TD5-RD6)	Trichera Dolina (TD5-RD6)			Shamin	Shamin	*Microtus arvalinus, P. posterius*
	EARLY			20-25			Kärlich B	Karlich B Pagliare di Sassa Chlum 6 Holstejn	TAMANIAN	Petro-pavlov-kian	Moiseevo 1 Petropav-lovka 2 Karai-Dubina	Petropavlovka 2 Karai-Dubina Log Krasnyi	*Microtus* ex gr. *oeconomus*= *M. ratticepoides*
							Untermass-feld (?)	Untermassfeld Betfia (B-V)		Morozov-kian	Port-Katon	Morozovka 1 Luzanovka Port-Katon	*Microtus (Terricola)* sp., *M.(Stenocranius) hintoni*
			0,99 1,07	26-30			Vallonnet Castagnone Colle Curti	Les Valerots Monte Peglia Vallparadis		Kairian (Ostro-gozhs-kian)	Korotoyak (Osrtogozh-skian suita) Margaritovo 1 Roksolany	Korotoyak (Osrtogozh-skian suita) Zapadnye Kairy Ushkalka Limany	*Prolagurus pannonicus*
				31	VILLA-NIAN		Sima del Elefante	Sima del Elefante		Nogais-kian		Nogaisk Tarkhankut	*Allophaiomys pliocaenicus*

Figure 1. Biostratigraphical scheme for the end of the Early Pleistocene – the beginning of the Middle Pleistocene for the territory of Europe.

Conclusion

The small mammal bone materials from the unique localities found in Chaudian deposits indicate directly the species composition and evolutionary level of faunas during the time of this transgression. They could be the basis for correlation between marine and continental events at the beginning of the Middle Pleistocene.

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Geochemical detection of chronological and paleoclimatic signals in fully marine to anomalohaline water bodies: The case of the Mediterranean, Black, and Caspian Seas

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Keywords: geochemistry, carbonates, ambient fluids, *paleoenvironment*, ***dating***

Introduction

Modern aquatic science relies heavily upon the investigation of chemical signals entrapped within skeletal parts of resident organisms to ensure better dating and paleoclimate reconstructions. For instance, decaying isotopes (^{14}C, Uranium-series) or $^{87}Sr/^{86}Sr$ are traditional methods that can yield a chronology for carbonate materials. Regarding the capability to extract information of climatic significance, at present a broad array of geochemical tools is available, depending upon the kind of information required. Paleotemperature assessment is one such key problem the solution of which can often be found through geochemistry (e.g., the analysis of stable and clumped oxygen isotopes, Li/Mg, Mg/Ca, and Sr/Ca ratios). Paleosalinity reconstruction can be obtained through $^{87}Sr/^{86}Sr$ ratios or stable oxygen isotope composition. Information on the nutrient content (trophic state) is recorded by phosphorus or cadmium content as well as carbon isotopes ($\delta^{13}C$) (e.g., Montagna et al., 2006), whereas pH levels (relevant to the topic of ocean acidification) can be deduced through $\delta^{11}B$ composition of carbonates (e.g., McCulloch et al., 2012). The $^{143}Nd/^{144}Nd$ composition (expressed as ε_{Nd}) is a tracer of water mass provenance and, therefore, ocean circulation (e.g., van de Flierdt and Frank, 2010).

However, the chemical heterogeneities observed at micron and nanometer size levels in biogenic carbonates suggest that the physiology imprints a “vital effect” upon different structural regions, which potentially complicates and distorts their interpretations and, hence, paleoceanographic reconstructions.

The final success of geochemical applications is also strongly dependent upon the existence and availability of suitable natural archives, and the progress in precision and accuracy of analytical instruments. Regarding the latter, thermal ionization and inductively coupled plasma mass spectrometers equipped with multi-collectors are the current state-of-the-art technologies, with ample margins for future improvements.

The potential value of geochemistry and some caveats for the Black and Caspian Seas

The methods reported above are at present the best descriptors on-stage within fully marine domains. This advantage correlates with two general aspects: (i) intrinsic attributes of ambient fluids, and (ii) the ecology of related organisms. These two aspects are of paramount importance when considering the region under scrutiny, encompassing the ‘marine’ Mediterranean Sea, the ‘brackish’ Black Sea, and the ‘anomalohaline’ Caspian Sea, and their latest Pleistocene to Present vicissitudes. First, the spatial and temporal distribution of some chemical elements in seawater is relatively constant (especially considering the long residence time of the conservative elements and the relatively short mixing time of the ocean), when compared to brackish, freshwater, or anomalohaline water bodies, whose chemical composition is more prone to substantial chemical and physical variations even on short temporary lapses (e.g., Major et al., 2006). Second, the types of life are directly controlled by the water peculiarities with the result that those organisms, traditionally suitable to be geochemically-checked for paleoenvironmental reconstructions, may simply be absent outside fully marine habitats. A case in point is provided by corals, which include some of the most widely used natural marine carbonate archives in modern paleoclimatology (Robinson et al., 2014). Calcified scleractinians and octocorals do not cross the Bosphorus, likely because of unsuitable lower salinities in the Black Sea. They seem to be equally absent in the Pleistocene record of these basins as well. Thus, the use of corals as paleoceanographic archives is limited to marine habitats *sensu strictu*. The same applies also to other non-carbonate skeletonized cnidarians of more limited paleoclimatic importance (e.g., Antipatharians). On the other hand, other marine calcifiers of established geochemistry-based climatic value, such as benthic bivalves, ostracods, and foraminifers, do occur in the Mediterranean, Black, and Caspian Seas (e.g., Yanko-Hombach et al., 2007). These groups even share taxa of marked euryhaline ecological attitude such as, for example, the bivalves *Cerastoderma* or the foraminifer *Ammonia*. Others are endemics in the Black and/or Caspian Seas, such as the bivalve *Didacna* spp., which calls as a prerequisite for any application, the construction of dedicated equations established by using modern organisms and their co-occurring ambient water.

Conclusion

A growing literature is stressing the role of these biogenic carbonates as proxies of ambient water attributes in freshwater to anomalohaline domains, mainly applying stable oxygen isotope, $^{87}Sr/^{86}Sr$ and Sr/Ca ratio geochemistry (e.g., Major et al., 2002; Bahr et al., 2006, Lahijani et al., 2007). Regarding geochronology, there have been attempts to use U/Th-dating of mollusk shells in the Black and Caspian Seas (Arslanov et al., 2002), although such a method offers notoriously ambiguous results with this kind of material even within certain marine contexts.

In general, it seems difficult at the present to obtain a sound carbonate-geochemistry-based paleoclimatic reconstruction for the Black and Caspian Seas and precursors with the level of quality comparable to what is obtainable in marine domains. Equally problematic, it appears also that the application of the other proxies (e.g., phosphorus, boron, and neodymium isotopes, Li/Mg) that receive at present so much credit for marine paleoceanographic purposes. However, the way is by now marked, and the time is ripe for investing more energy in the experimental field of carbonate geochemistry of brackish to anomalohaline basins with the goal of improving our tools and unveiling the history of their changes. In such a perspective, a major advance is that biogenic carbonates are consistently present and often abundant in Pleistocene to Holocene sediments of this region, as documented by core and outcrop records (e.g., Genov and Peychev, 2001; Yanko-Hombach et al., 2007; Lericolais et al., 2010; Taviani et al., 2014), providing still underworked geochemical archives.

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The North Caucasus: Environmental changes during the Akchagylian and the Apsheronian according to pollen data

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Keywords: Late Pliocene-Pleistocene vegetation and climate

Introduction

Pliocene and Pleistocene deposits are widely distributed within the southeastern part of the East European Plain. For the Upper Pliocene and Pleistocene of the North Caspian region, the following paleomagnetic boundaries are accepted: the top of the Apsheronian is placed at the border of paleomagnetic chrons Matuyama/Brunhes, 0.78 Ma; the Akchagylian/Apsheronian boundary is at the top of the Olduvai paleomagnetic episode in the 1.64–1.66 Ma interval; the base of the Akchagylian is at the boundary between the Gilbert and Gauss paleomagnetic chrons, at around 3.4 Ma. The base of Mediterranean Piacenzian, approximately comparable to the beginning of the Akchagylian of the Caspian region, coincides with the magnetic reversal from the Gilbert to Gauss chrons. The west European Gelasian begins about 103.2 thousand years above the Gauss/Matuyama boundary at around 2.6 Ma with a maximum transgression of the Akchagylian sea.

Results of palynological studies of deposits laid down during the Akchagylian-Apsheronian transgression formed the basis for reconstructing the vegetation and climate conditions of the Precaucasus. In the North Caucasus (the Caucasian Mineralnye Vody area, the Tersko-Sunzhensky area, and the foothills of Dagestan), the Akchagylian and the Apsheronian have been investigated much less palynologically than in the northern Precaspian (Naidina, 1999).

Methodology

Samples for palynological analysis were selected from sections with characterized fauna and opened with wells to the southeast of Pyatigorsk and around Kizlyar. Also, research samples were taken from several natural outcrops in the basin of the Terek and Sunzha rivers. Pollen and spores were separated using centrifugation with a cadmium solution followed by acetolysis. Definition and calculation of pollen and spores were made on a "Laboval" microscope at 400x magnification.

Change in structure of the flora and vegetation forms the basis for stratification of the deposits according to pollen analysis, and the sequence is closely connected with changes in climatic conditions. Reconstruction of vegetation and climatic conditions was achieved with the use of plant indicators as well as plant groups with specific ecological requirements regarding temperature and humidity. Paleogeographical analysis of fossil dendroflora was applied to the interpretation of palynological data.

Results

Pollen assemblages were studied to produce a reconstruction of vegetation from the Akchagylian-Apsheronian in the North Caucasus. Comparison of pollen assemblages and restoration of vegetation in these regions showed some similarities and distinctions reflecting the variety in vegetation types. So, for the Tersko-Sunzhensky area in the Akchagylian formations, broad-leaved forests with participation of coniferous forms were characteristic. Near the Caucasus Mineralnye Vody region, coniferous forests with a *Tsuga* prevailed, and climate was cooler than in the Tersko-Sunzhensky area. Probably, these distinctions are explained by the influence of vertical zonation.

At the same time, the reconstructed vegetation of the area around Mineralnye Vody in the Caucasus comes nearer to the Middle Akchagylian coniferous forests that existed in Eastern Precaspian (Naidina, 1999). In the Akchagylian, flora including species from North America (*Taxodium*), East Asia (*Ginkgo*, *Keteleeria*, *Sciadopytis*, *Glyptostrobus*, *Engelhartia*), America-East Asia (*Tsuga*, *Carya*, *Morus*, *Nyssa*), America-Mediterranean-Asia (*Castanea*, *Juglans*, *Pterocarya*, *Zelkova*, *Rhus*, *Liquidambar*, *Elaeagnus*) appeared, all geographical groups alien to the modern flora. Since the Akchagylian, floral representatives of the pan-holarctic geographical group (*Abies*, *Picea*, *Pinus*, *Juniperus*, *Salix*, *Betula*, *Alnus*, *Myrica*, *Cornus*, *Rhamnus*) start to occupy a dominant position. Analysis of dendroflora shows that the following tendencies were demonstrated in the Akchagylian and Apsheronian: change in ratio of geographical elements of the flora, degradation of thermophilic elements, and formation of a forest with new edificators.

Throughout the Akchagylian and the Apsheronian, vegetation cover of the northern Caucasus gradually changed: forest formations were replaced by steppe vegetation developing under conditions of aridization.

Conclusions

Thus, as palynological research has shown, to an extent in the Akchagylian and the Apsheronian, there was growth in climate aridity and a decrease in heat security, revealed in the structure of the dendroflora. Essential climatic changes between the Late Akchagylian and the Apsheronian is not noted based on palynological materials (Naidina, 1999). Lack of a clear boundary between the Late Pliocene and the Early Pleistocene is registered by many researchers (Velichko et al., 2011).

According to palynological data, the beginning of the Akchagylian coincides with a noticeable change in the ratio of basic elements of the flora. In the Mediterranean, a transition from subtropical climate to a dry summer season happened (Suc, 1984). At the paleomagnetic reversal of Gauss/Matuyama in the Middle Akchagylian, a cooling is expressed in the expansion of coniferous forests into the Precaucasus. The maximum cooling occurred just about 2.6 Ma, which is also traced globally based on the study of pollen charts and data from the analysis of marine and continental deposits (Suc et al., 1997).

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Carcinogenic fibrous zeolites of Georgia (Southern Caucasus): Hazardous areas and measures of protection

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Keywords: Erionite, mordenite, mazzite, volcanic tuffs, Vardzia flow

The World Health Organization classified fibrous zeolites (erionite, mordenite, phillipsite, ferrierite, mazzite, offretite and roganite) as the carcinogenic (class 1) natural minerals. According to this classification, based on direct evidence in human and animal studies and in intraperitoneal experiments, erionite is the most dangerous toxic mineral, which is 20–40 times more toxic than asbestos-chrysotile and 7–20 times more active than asbestos-crocidolite.

Modern research shows that fibrous zeolites cause regional epidemics of malignant neoplasias (bronchial carcinoma, malignant mesothelioma). The first such epidemic occurred in Cappadocia, Turkey, where the populations of several villages suffered from pleural mesothelioma, and more than 50% of the inhabitants died. As research has shown, the cause of the disease was erionite-bearing volcanic rocks that were used as building materials in the villages, including its presence in plasters used within homes. Deterioration of these materials together with the dry and windy environment led to inhalation of erionite fibers; this was definitively determined to be the cause of the regional epidemic malignant neoplasias (Baris et al., 1978).

Zeolites are formed in volcanic ash and pyroclastic rocks as result of diagenetic and hydrothermal alteration. Erionite and other fibrous zeolites are formed in the mixed environment of volcanic ash and clay. Fibrous zeolites are often found in association with other zeolites, precisely with clinoptilolite and chabazite.

In the Southern Caucasus, volcanic formations are widespread and occupy about 30% of the total area. Generally, the Caucasus represents a Phanerozoic collisional orogen, which was formed along the Eurasian North continental margin, over more than 1200 km, between the Black and Caspian seas, and currently it is an expression of the continental collision between the Arabian and Eurasian lithospheric plates. As a result of Middle and Upper Jurassic, Upper Cretaceous, Oligocene, Eocene, and Pliocene-Holocene thermal activity, volcanogenic-sedimentary rocks were formed in the orogen. Greater quantities of zeolites are concentrated in the Middle Jurassic, Upper Cretaceous, and Eocene formations. The areas of distribution of these rocks are either densely populated or they represent agricultural lands.

In Georgia, zeolites have been studied relatively well (Skhirtladze, 1991), but identification of fibrous zeolites has not been conducted, as their danger was not understood. The work carried out by the authors has shown that fibrous zeolites are widely distributed over the territory of Georgia. Zeolites, with erionite and mordenite, are found in the Mtkvari, Enguri, and Algeti river gorges, within the zeolite deposit of Tedzami, the barite-polymetallic deposit of David-Gareji, and the copper polymetallic deposit of Abulmulak, and also in the areas surrounding the villages of Askana, Vardzia, Bolnisi, Ratevani, Abrameti, Samshvilde, and Nichbisi. In terms of climate and structural context, these areas are similar to nearby Cappadocia province, and with great probability, they represent the most likely zeolitic danger for the population (Okrostsvaridze et al., 2011).

Especially similar to the rocks of Cappadocia province are the tuffs of the Vardzia flow (Meskheti province, South Georgia). These represent caked flow tuffs, with a thickness that varies from 45 to 60 meters and which extends more than 20 km in distance. The Vardzia flow is not graded and mainly consists of medium to poorly-caked tuffs, the color of which depends on the degree of sintering and varies from pink to white. Binder material basically consists of volcanic ash, which as a result of low-temperature hydrothermal processes was transformed into a zeolite, in particular, mordenite. Beacons' Vardzia flow tuffs are very easily cut with a knife that was successfully applied by ancient builders and they, in the 12th century, build hear the Vardzia cave city. Builders did not know anything about the geo-environmental hazard posed by the fibrous zeolites in these rocks. We investigated the historical sources of the region and discovered that the life of people living there did not exceed 50–55 years. More information exists about the disease of Queen Tamara. It is known that she died at the age of 53 and was ill only during the last two months of her life (Samushia, 2010). In addition, all her symptoms coincide with those of typical mesothelioma, which was probably caused by her long-term exposure due to living in Vardzia.

We believe that for prevention of harm from fibrous zeolites, the country needs to implement the following measures: (1) conduct research across the population on mesothelioma occurrence within potentially dangerous areas and define the geography of the disease; (2) form a special laboratory for the identification of fibrous zeolites in volcanic rocks; (3) digitize a map of the distribution of fibrous zeolites for the whole area; and (4) stop the use of zeolites with fibrous minerals in agriculture, construction, and the food industry.

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Micropaleonthological data from the northeastern abyssal part of the Black Sea (the Russian sector)

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Keywords: Quaternary, Holocene, foraminifers, ostracods, Bugazian and Vityazevian layers, Kalamitian layers

The shelf sediments of the Quaternary period, continental slope, and abyssal plain present continuous sections of mainly marine origin (but alluvium is rarely found also, including buried deposits), accumulated under conditions of sea-level change. The sedimentation sharply reacted to fluctuations in sea level with amplitudes ranging from a few meters to several tens of meters. On the abyssal plain, such fluctuations have almost no effect on the sedimentation lithology, and are recognized only through micropaleontological research. Presently, there is a bio-stratigraphic subdivision of the Black Sea Quaternary sediments: by mollusks (Nevesskaya, 1965; Il'ina, 1966; Fedorov, 1978), by foraminifers (Yanko, 1990), and by ostracods (Yanko and Gramova, 1987). These subdivisions were made in the course of research conducted on the offshore part of the basin mainly. The authors of these theses were fortunate to study samples taken primarily on the continental slope and the abyssal plain in the Russian sector of sheets K-37 X (underwater canyon Mzymty) and K-37-XVI (Abyssal 16).

We researched foraminifers and ostracods from bottom samples taken by the research and production association "Yuzhmorinzhgeo" in 2013–2014. The sea depths in the sampled sites range from 700 meters to 2,150 meters, and the sampling intervals in the cores ranged from 10 cm to 350 cm. The samples contain silty sediments (sometimes gas-saturated), often enriched with iron sulfides (hydrotroilite, pyrite), with masses of pseudohexagonal crystals of snow-white gypsum; the shells of mollusks are found quite rarely. Most of the samples contained ostracods, foraminifers, small fragments of mollusk shells, and massive quantities of molluscan larvae. The composition of foraminifers in deep-sea samples is relatively poor and contains representatives of the following genera: *Ammonia*, *Porosononion*, *Mayerella*, etc. The ostracod composition is more diverse and contains representatives of the following genera: *Cyprideis*, *Xestoleberis*, *Leptocythere*, *Loxoconcha*, *Candonan*, and others.

While comparing the recovered microfauna along the dissections of the columns, levels of alternating layers were detected: alternations of foraminifera, ostracods, larval shells of mollusks, and layers with no fauna present. The detected layers make it possible to reconstruct the stages of deposition in the Holocene period. During regressions, the deep sea area was closer to the sources of fragmental material drift; the silts often contain Holocene microfauna with the inclusion of shells of more ancient re-deposited fauna, introduced from the Caucasian uplifts. During transgressions, the conditions of sediment accumulation in deep sea areas were stable and accompanied by the deposition of mainly silty sediments with rare inclusions of microfauna.

According to the precursors' materials (Nevesskaya, 1965; Shcherbakov et al., 1983; Kuprin et al., 1985; Shimkus, 2005), the calcareous ancient Black Sea clayey silts, rich in organic matter, appear in the underlying Neoeuxinian sediments. These silts are assigned to the Bugazian and Vityazevian layers. The silts were deposited on strongly sulphidized hydrotroilite silts (the Neoeuxinian top cover) and are overlapped with sapropel (putrid ooze)-like silts of Kalamitian age (Shcherbakov, 1983). The thickness of Holocene layer on the continental slope and on the abyssal is greater than on the shelf.

Thus, in the early Holocene period, the Neoeuxinian complexes were gradually substituted with Mediterranean fauna complexes, and representatives of the salt-water and brackish-water fauna existed together. The transgressive Bugazian and Vityazevian complexes are related to the phases of salinization and colonization by Mediterranean organisms. The Dzhemetinian complex is related to the greatest transgression and thermal maximum of Holocene. The mass florescence of fauna was associated not only with Mediterranean faunal transgressions and migration, but also with the expansion of the sea's shallow areas. The late ancient Black Sea sediments of the Kalamitian horizon are represented by silts with the inclusion of *Mytilus galloprovincialis* mollusk shells and rare *Cardium edule* shells also. The Kalamitian layers are the marker horizon, followed by increased accumulation of organic sapropel substance.

Research into the bottom samples still goes on, and material for a more reasoned stratigraphic subdivision of the Quaternary formations is being prepared now.

Acknowledgments

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Variation in field chlorophyll *"a"* on the northwestern Black Sea shelf (data from satellite observations)

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Introduction

The northwestern Black Sea shelf (NWBS) is an extensive shallow water area with a depth less than 50 m that occupies more than 75% of the sea's total shelf area. It has a long border with the deep-water part of the Black Sea and an intense two-way water exchange. The contribution of freshwater components made by the rivers Danube, Dnieper, Southern Bug, and Dniester are the determining factor in the formation of the hydrological regime of the region. Horizontal and vertical thermohaline heterogeneity and sharp reactions to thermodynamic atmospheric effects are characteristic for waters of the NWBS. Although the NWBS has a relatively small volume of water, changes to the full water body can take a long time to occur. Changes in the type of atmospheric circulation are the cause of multidirectional processes in the flow dynamics. Compounding climatic change and variability in meteorological parameters in the atmosphere and waters of the northwestern Black Sea, continued anthropogenic pressures can lead to the formation of zones with significant concentrations of pollutants and intense algal blooms. The natural circulation system is unable to "unload" these zones.

The distribution of phytoplankton on the surface of the sea is one of the most important indicators of both the trophic status of aquatic ecosystems and the mesoscale dynamic structure of the reservoir. Satellite data reflecting the concentration of chlorophyll "*a*"—the main photosynthetic pigment contained in various types of phytoplankton, have been widely used in recent decades. Ease of operation and regularity of availability of satellite data about the distribution of chlorophyll *a* (Chl_a) in space and time is a major advantage of remote sensing compared to the always small sample numbers, labor-intensiveness, and expense of field observations.

Observational data

Initial information came from results of research expeditions in the Black Sea: (1) database of the hydrophysical sector of the Ukrainian Scientific Center of Ecology of the Sea for the period 1955–2005, and (2) archival data of hydrometeorological observations from the Black and Azov Seas Centre for Hydrometeorology (BASCHM). Satellite data digitized and averaged over a week have also been used to study the seasonal and interannual dynamics of Chl_a concentrations. These data, as well as sea surface temperature, were read from NASA sites with a spatial resolution of 4x4 km (http://oceancolor.gsfc.nasa.gov). In this paper, we analyzed the quantitative and qualitative characteristics of the field concentration of chlorophyll, namely the space-time series of the local maximum values of "outbreaks of phytoplankton bloom" for homogeneous zones of the NWBS. Analysis of standard satellite products and the biological characteristics of the upper layer of Black Sea water (in particular, the correction and restoration of Chl_a concentration by using regional algorithms) is given in Suslin et al. (2008).

Zoning of waters of the northwestern Black Sea shelf

Fig. 1 shows the areas of the NWBS with relatively homogeneous properties of water masses in thermohaline indexes. The technique of volumetric-statistical analysis (θ, S - analysis, where θ - potential temperature, and S - salinity) of water masses was used to determine the boundaries of these areas (Ukrainskyi et al., 2006). The volumetric-statistical θ, S - analysis of NWBS water allowed us to identify seven homogeneous areas (1–7), which are delineated in Fig. 1 by thick straight lines and numbered by large digits. A detailed description of the shelf water masses for these zones is given in (Ukrainskyi et al., 2006). Three of the areas are weakly transformed river waters from major river systems: the Danube (1), the Dniester (2), and the Dnieper-Bug (3), all of which are in the coastal areas of the western part of the sea. The border zone of the most intense transformation of river water (5) is located seaward; the waters of the open sea are in the southeastern sector of the NWBS: in the shelf area (zone 6) and in the area of the continental slope (zone 7). Waters of Karkinitsky Bay (zone 4) have a special thermohaline regime that differs significantly from the regime of the surrounding waters. In the summer, they are fresher, mainly due to the spread along the Tendra Peninsula coast of water from the Dnieper-Bug river flow, and vice versa in the winter when more saline water arrives due to active coastal upwelling.

Analysis of the various processes within these homogeneous areas gives much additional information on the space-time structure of chlorophyll fields that had previously eluded researchers due to the variability of processes for the entire area.

Time-spatial variability of chlorophyll *a* in the waters of the NWBS surface layer

The water area of the NWBS was divided into 53 twenty-minute trapezoids (with sides of about 20 miles) to provide a sufficiently detailed description of the variability of the Chl_a field. Analysis of the time-spatial variability of Chl_a was conducted on samples of a nine-year series (1998–2007) of satellite observations. The averaging of monthly data was done to obtain more stable estimates (in a statistical sense) of regularities in the seasonal variability of chlorophyll. Time series Chl_a and sea surface temperatures with weekly discreteness for characteristic plots of each homogeneous region are shown in the insets in Fig. 1. The maximum values of fluctuations in Chl_a concentration were in areas of accumulated river flow and in Karkinitsky Bay (areas 1–4). The amplitude of the annual fluctuations there reaches 50 mg/m^3. Extremes of Chl_a in the mixing zone (region 5) have values a bit more than 10 mg/m^3. The concentration of Chl_a shows values of 0.2–0.5 mg/m^3 in the waters of areas 6 and 7 during the summer, and in the cold half of the year, they reach values of 1.0–2.0 mg/m^3.

Dispersion of the physical parameter (in this case, the concentration of Chl_a) was determined by the amplitude of oscillation in this parameter over time and space. The dispersion of the nine-year series Chl_a with weekly discreteness was calculated for each of 53 trapezoids. Energy characteristic of the fluctuations in the concentration of Chl_a was obtained through the evaluation of its dispersion. A temporary energy fluctuation of chlorophyll is closely associated with the distribution of nutrient-rich river water on the shelf. Comparison of the location of the boundaries of the homogeneous regions and the distribution of dispersion variability of chlorophyll *a* confirms this. Maximum dispersion of oscillations takes place in the estuarine areas of the Dnieper and Danube, as well as in the corner of Karkinitsky Gulf, i.e., in areas of accumulation of river water. Dispersion is gradually reduced to almost zero values in the southeastern sector of the NWBS, where the purest water of the high seas is located.

The values of dispersion in 30 and more units (mg\m^3) (Fig. 1) can be used to identify individual areas with the most eutrophic waters immediately adjacent to the estuarine areas of the three river systems in the NWBS. Line 10 demarcates areas of weakly transformed river water and zone 5 (intense transformation), and the isoline in 1 unit is partition between the last and areas 6 and 7 (Fig. 1). Thus, the spatial distribution of the dispersion characteristics of the concentration of Chl_a allows reliable establishment of averaged boundaries between water masses through the stages of their transformation in the NWBS.

Interannual changes in the concentration of chlorophyll in the waters of the open shelf are characterized by a relatively high level, noted in 1998–2001 (2–5 mg\m^3). Concentration decreased significantly over the next six years to values of 0.5–2 mg\m^3. It should be noted that the concentration of Chl_a is not related directly to the temperature of the surface waters, but as shown above, the concentrations of Chl_a are in reasonably good agreement with the spatial distribution of different degrees of biological “contamination" of the water.

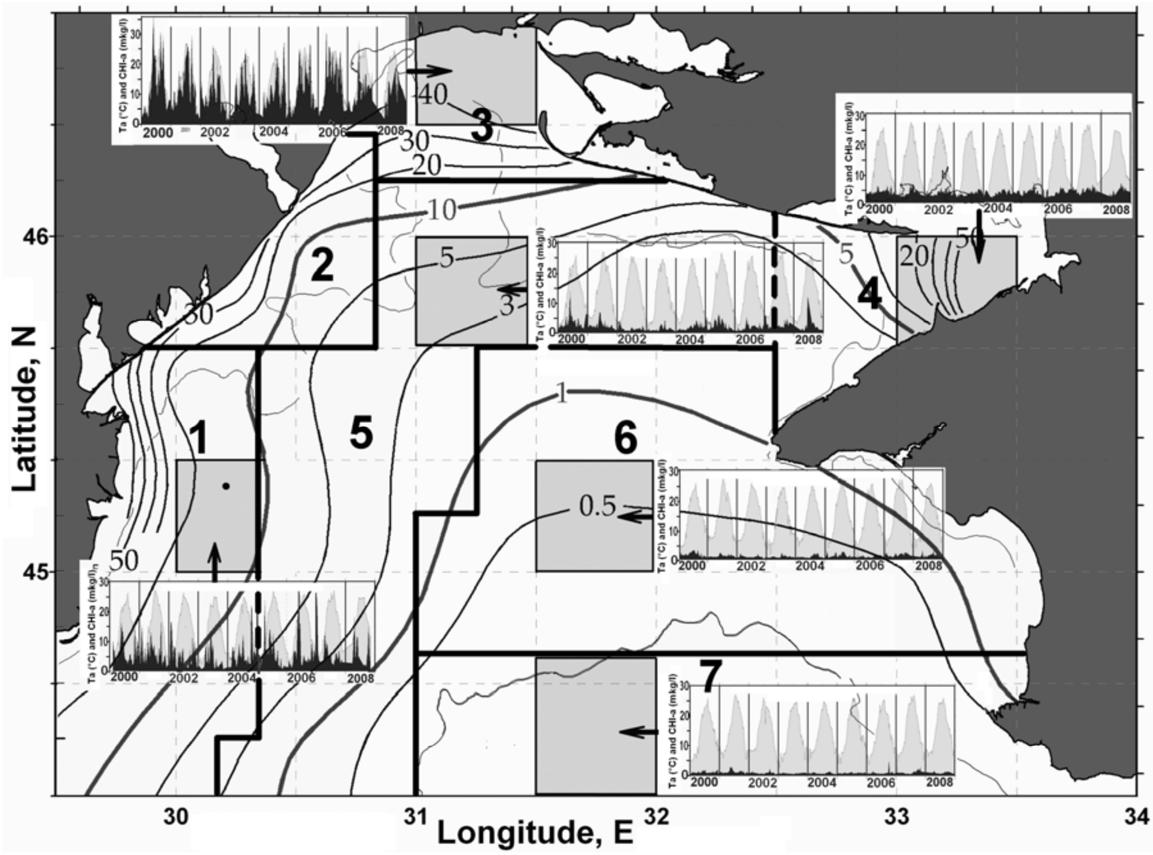

Figure 1. Combined scheme of water zoning in the NWBS for thermohaline parameters and the distribution in dispersion of temporary changes in the concentration of Chl_a (isolines, %). The insets show the time series of Chl_a (dark background) and water temperature (light background) in the surface layer of the NWBS.

Propagation of river water within the NWBS is determined largely by wind conditions. The data from observations on the wind at Odessa clearly indicate a decrease in wind speed over the climatic time scale. During the past 30 years, the average wind speed modulus decreased by almost 30% (from 1.25 to 0.85 m/s in the summer season and from 2.2 to 1.5 m/s in the winter). Duration of the northern component of the wind increased slightly, while the western component simultaneously decreased. It did not contribute to the spread of river water in the open sea area. Observations on the salinity of the surface layer near Zmeinyi Island showed that in the decade of the 1980s, a salinity less than 4 psu was observed 23 times, but in the next decade, only 4 times, i.e., the west wind component had a significantly reduced impact on surface water masses in the NWBS (Popov et al., 2009).

Intra-annual variability of Chl_a in the areas of the river mouths is significantly different from the rest of the shelf. Here, the maximum concentration of Chl_a is clearly concentrated in the spring season (60–70%), while in the central (zone 5) and in the southeastern regions, the high level of Chl_a in the NWBS is “blurred” in winter (30–55%), spring (about 40%), and summer (8–25%) seasons (Table 1). An active phytoplankton bloom was not observed in the autumn months.

The water area of Karkinitsky Bay in the summer is filled by the Dnieper-Bug flow. Algal blooms are somewhat shifted in time relative to the area of the mouth of the Dnieper-Bug estuary. The essential difference in the biological rhythms in Karkinitsky Bay is the relatively frequent occurrence in winter (20%), mainly in January, of “outbreaks” of Chl_a on its seaward side (the widest part) due to upwelling phenomena and, consequently, the rise of nutrients from deep layers. The southeastern sector of the NWBS (the region with a predominance of open sea water in zones 6 and 7) is characterized by winter and spring peaks of Chl_a, summer peaks noticeably smaller, and autumn blooms virtually absent.

The predominance of flowering in the spring season 1998–2001 in the open waters of the NWBS shifted to the winter season 2002–2007 (Table 1). To a certain extent, this can be explained by the fact that species structure of the phytoplankton community in open areas of the NWBS changed. Climatic increase in sea water temperature of the NWBS promoted the change in species composition of phytoplankton also (Matygin et al., 2013).

Dependence between the areas (the total number of trapezoids) with the "outbreaks" of Chl_a concentrations, average monthly air temperature, and average monthly volume of river runoff are shown in the form of a volumetric diagram in Fig. 2a. Fig. 2b shows a similar dependence, but the volume of river runoff is shifted back in time by one month. In this case, the concentrations of the isolines and the extreme peaks of Chl_a are noticeable.

The total area of "outbreaks" agrees significantly with the previous runoff of rivers in the phase space: the air temperature and the total river runoff. This is evidence of significant inertial spread of river water in the NWBS.

Table 1. Seasonal distribution of the number of peaks in concentration of Chl_a in the homogeneous areas of the NWBS (W = winter, Sp = spring, Sm = summer, A = autumn).

Year	1 region				2 region				3 region			
season	**W**	**Sp**	**Sm**	**A**	**W**	**Sp**	**Sm**	**A**	**W**	**Sp**	**Sm**	**A**
1998	9	7	5	0	0	8	1	0	0	4	1	0
1999	1	9	2	0	0	8	2	0	0	2	0	0
2000	2	12	0	0	2	5	0	0	0	3	0	0
2001	3	10	3	0	3	7	3	0	0	3	4	0
2002	9	8	0	0	7	4	0	0	0	3	3	0
2003	0	10	0	0	0	4	1	0	1	3	2	0
2004	5	5	4	0	1	5	1	0	0	3	1	0
2005	6	11	3	0	2	7	2	0	0	3	1	0
2006	1	8	1	0	0	8	1	0	0	4	1	0
2007	6	9	1	0	0	5	1	0	0	1	1	0
∑ season	**42**	**89**	**19**	**0**	**15**	**61**	**12**	**0**	**1**	**29**	**14**	**0**
%	**28**	**59.3**	**12.7**	**0**	**17**	**69.3**	**13.6**	**0**	**2.2**	**65.9**	**31.8**	**0**

Continuation of Table 1.

Year	4 region				5 region				6 region				7 region			
season	**W**	**Sp**	**Sm**	**A**	**W**	**Sp**	**Sm**	**A**	**W**	**Sp**	**Sm**	**A**	**W**	**Sp**	**Sm**	**A**
1998	1	2	7	0	6	4	11	0	5	9	13	6	4	6	1	0
1999	4	3	7	2	5	10	3	0	3	12	0	0	2	5	0	0
2000	0	4	7	1	5	17	3	0	4	12	8	0	4	8	1	0
2001	0	4	9	1	4	11	4	0	3	16	0	0	2	7	0	0
2002	3	4	2	0	17	2	0	0	12	1	2	0	6	0	1	0
2003	2	2	3	1	0	8	9	0	6	7	5	0	6	1	0	0
2004	2	1	4	0	6	4	10	1	9	1	7	3	13	0	0	0
2005	4	2	4	0	6	14	10	0	10	9	6	0	0	6	1	0
2006	1	5	4	0	1	15	3	0	5	12	0	1	8	0	0	0
2007	4	0	6	0	12	7	5	0	15	0	10	0	8	0	4	0
∑ season	**21**	**27**	**53**	**5**	**62**	**92**	**58**	**1**	**72**	**79**	**51**	**10**	**53**	**33**	**8**	**0**
%	20	**25**	**50**	**5**	**29**	**43**	**27**	**0.5**	**33**	**37**	**24**	**4.7**	**56**	**35**	**8.5**	**0**

The maximum areas of the spring-summer peaks in the concentration of Chl_a mainly correspond to periods of high water with total river runoff greater than 11,000 m^3/s and an ambient temperature of 15–21°C, Fig. 2b. Two cases of extreme summer spread of "outbreaks" (more than 40 trapezoids contemporaneously) were observed in June 2000 and 2001. Note that the average air temperatures were low for these months (respectively, 19.8 and 18.6°C).

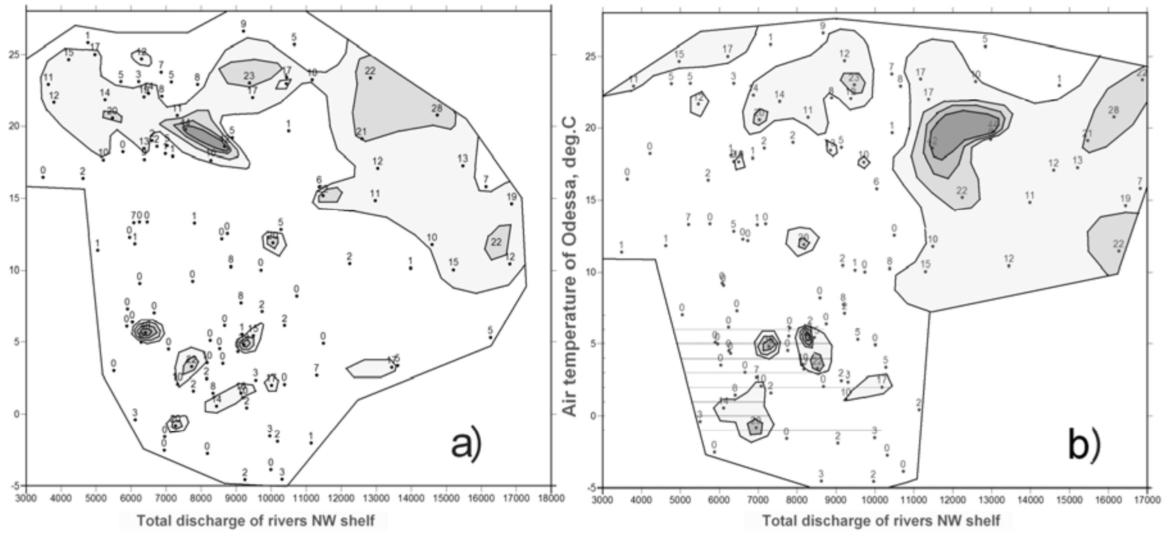

Figure 2. Diagram depicting the areas of “outbreak" propagation for chlorophyll *a* from air temperature; a) synchronous on time of river runoff; b) with the previous (shift 1 month) runoff of rivers.

Maximum areas of winter phytoplankton blooms in the waters of the NWBS occurred when the average monthly total runoff of rivers was 7000–9000 m^3/s and the air temperature was in the range of 4–6°C. Two cases of extreme propagation of winter “outbreaks" of chlorophyll (at a level comparable to summer) took place in February 2002 and January 2007. Temperature conditions were very warm for these months (respectively, +4.8 and +5.6°C). This is reflected in the presence of sharp peaks in the lower part of Fig. 2, and it indicates a significant area with phytoplankton blooms.

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EUXINUS: Real time network for marine environmental monitoring of the western Black Sea

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Keywords: offshore observatories, long-term data, underwater sensors

An important project involving Romanian-Bulgarian cooperation was established last year to initiate a new and complex environmental monitoring system in the western Black Sea. The system consists of five offshore observatories, each including three modules—surface, mid-water, and bottom, and a coastal gauge limited to the surface buoy. The system, unique in the Black Sea area, is able to collect long-term data for several key environmental parameters in real time.

Each of the offshore observatories consists of three main units: a Surface Relay Buoy (SRB), an Instrumented Mooring Line (IML), and an Underwater Tsunami Module (UTM).

Among the observatories, three of the Surface Relay Buoys are equipped with a weather station continuously measuring the following parameters: wind speed and direction, temperature, pressure, and relative humidity, all corrected by a heading sensor for wind direction and buoy rotation.

The SRB of each observatory is equipped with an environmental monitoring instrument pack mounted on the buoy pole at 5 m water depth. The instrument pack includes a Doppler current meter, classic CTD sensors (conductivity, temperature, pressure), and sensors for measuring dissolved oxygen concentration, turbidity, and chlorophyll concentration (Table 1).

Table 1. Characteristics of the observatory sensors.

Sensor type	Manufacturer	Parameter	Range	Accuracy	Module
All-in-One Weather Sensor	Climatronics	Wind speed (w.s.)	0–50 m/s	±0.5 m/s	SRB
		Wind direction	0–360°	±5°@w.s. +2.2 m/s	SRB
		Temperature	–40°C to +50°C	±0.2°C	SRB
		Relative humidity	0–100%	±3%	CG
		Pressure	600–1100 hPa	±0.35 hPa@25°C	
		Compass		±2°	
Z Pulse Doppler current sensor	Aanderaa	Current speed	0–300 cm/s	±0.15 cm/s	SRB@IML
		Current direction	0–360°	±5° for 0–15° tilt	
		Tilt	Magnetic 0–45°	±1.5°	
AADI Optode 4835	Aanderaa	Oxygen concentration	0–500 μM	<8 μM	SRB
		Air saturation	0–150%	<5%	
AADI 4880/4880R	Aanderaa	Temperature	–4 to +36°C	±0.03°C	SRB@IML
AADI 4319B	Aanderaa	Conductivity	0–75 mS/cm	±0.0018 S/m	SRB@IML
		Temperature	–5 to +40°C	±0.1°C	
AADI 4112B	Aanderaa	Turbidity	0–500 FTU	200 mV/FTU	SRB
AADI 4646C	Aanderaa	Pressure	0–3100 kPa, ~300 m	±0.04% FSO	SRB@IML
		Temperature	0–36°C	±0.2°C	
CYCLOPS-7	Turner Design	Chlorophyll *in vivo*	0–500 μg/l	MDL = 0.025 μg/l	SRB

The Instrument Mooring Line package is located on the mooring line of each observatory, at 20 m above the bottom of the sea. This package consists of a Doppler current meter (Table 1) and classic CTD sensors, together with an acoustic modem for data transmission to the SRB. From the SRB, the data are retransmitted via satellite link to shore facilities.

The SRB and IML instrument packages are switched on every hour and data are acquired, stored in the mass memory, and transmitted to the shore facilities, together with the weather data averaged for 1 hour.

The entire data package transmitted from the EUXINUS network to the centers is stored and analyzed via a specially designed software package called GEM 2.1, that aims to store historical data on a web-based platform developed in PHP and Java EE to handle both data elaborations and visualization procedures in a platform independent environment. The program is based on several modules, the main module containing all the functions needed to organize the data acquisition network and measurement definition.

The data are organized in a hierarchical way, starting from networks and ending with measurement data and the report module.

Each measurement can have a set of measurement ranges attached, to allow checking if a value is in a "normal" range. In case a value is not within the normal range, the user has the possibility to define what happens with those values. The data can be treated as normal, be replaced by a defined value or the data can be invalidated and not used in the computations. Also, a text is displayed when a value is not within the defined range.

Each measurement value can have a set of thresholds defined. The following measurement value thresholds can be defined: For single values - the test is performed for each average; For consecutive values - the test is performed against multiple consecutive averages. The comparison can be of the following types: Simple comparison for testing against a single value (<, <=, >, >=, =, < >); Interval comparison for testing the value against an interval (In interval, Outside of interval).

The EUXINUS system has been online from June 2013 and has already proven itself to be a valuable tool for collecting long-term environmental data useful for continuously monitoring marine water quality in real time. The constantly growing database will provide much needed long-term data for the scientific community.

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The structure of a free-living nematode taxocene in industrially polluted waters (Sevastopol Bay, Black Sea)

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Keywords: biodiversity, abundance, species composition, trophic structure, soft bottom habitats

Due to its geographical location, Sevastopol Bay is one of the most studied areas along the Crimean Black Sea coast. In soft bottom habitats of the bay, free-living nematodes are the dominant meiobenthic taxa. However, studies of the nematode taxocene are not numerous (Filip'ev, 1918; Sergeeva and Mazlumyan, 1988, 2008; Ivanova and Kosheleva, 2012).

Methods

The material was collected at 18 stations at a range of depths between 1.5–17 m (Fig. 1) in May of 2013. At each station, three replicate samples were collected by 18 cm^2 tube from the surface of the bottom monolith lifted by Petersen grab. The sediments were washed through a set of sieves with mesh sizes of 64 µm, and stained with Rose Bengal for further study of organisms under a light microscope. We extracted only those specimens that stained intensely with Rose Bengal and showed no sign of morphological damage. Specimens were mounted into temporary glycerin slides. These slides were then studied with a Nikon Eclipse E200 light microscope. At each station, an additional sample was taken for particle size analysis (Klenova, 1948). The trophic structure of the nematode taxocene was based on Wieser (1953). Data processing was carried out using the PRIMER V 5.2.8 package (Clarke and Gorley, 2001). Assessment of species composition similarity was performed using clustering with the complete linkage of the Bray-Curtis similarity measure (program CLUSTER) and based on a log-transformed matrix of species abundance values.

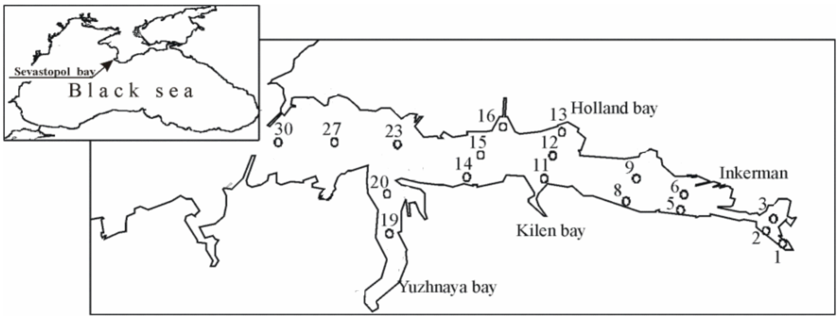

Figure 1. Study area and location of sampling stations in Sevastopol Bay (May, 2013).

Nematode abundance ranged from 6×10^3 to 780×10^3 ind.m^{-2}, with an average of 196×103 ind.m^{-2}. Nematodes make up 34–95% of total meiobenthos (fig. 2A), which is specific for silty sediments with a high organic matter content.

A total of 60 nematode species belonging to 6 orders, 14 families, and 37 genera was recorded. On the most polluted sites (station 19: petroleum hydrocarbons and chloroform-extractable compounds), an unexpectedly great number of species (n = 22) was observed. Depleted species composition (n = 6) was observed in the innermost part of the bay (stations 1, 5, 13).

Sabatieria pulchra (G. Schneider, 1906) is the dominant species with occurrence in 100% samples. This species is considered stable under different environmental stresses and hypoxia (Heip et al., 1985). The abundance values of *S. pulchra* ranged from 6095 (station 14) to 156,050 ind.m^2 (station 27), with the average number being 47,816 ind.m^2, which is two times greater than the abundance of the subdominant species *Axonolaimus ponticus* Filip'ev, 1918 (n = 29,927 ind.m^{-2}) and *Aponema* sp.1 (n = 20,337 ind.m^{-2}).

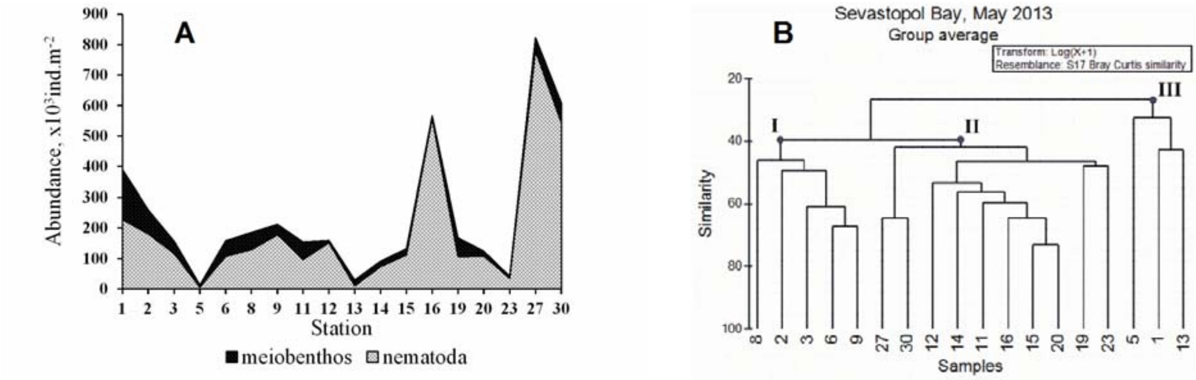

Figure 2. Abundance distribution of meiobenthos and free-living nematodes (A); cluster dendrograph of meiobenthos stations (B) from Sevastopol Bay, May 2013.

In Sevastopol Bay, the nematode taxocene composition was rather homogeneous. Similarity between stations (Bray-Curtys Similarity) is at least 25% (Fig. 2B). Based on a limit of 40% similarity, all stations can be put into two main complexes: the first complex (I) included 5 stations, and the second complex (II) included 10 stations; a third marginal group (III) included 3 stations.

The trophic structure of the nematode taxocene (Fig. 3) is represented by all defined groups (Wieser, 1953). Non-selective deposit feeders dominated at all stations (33–83%). Selective deposit feeders (8–33%) and epigrowth feeders (7–33%) were less represented. The share of predators/omnivores was significantly higher than 33% within the innermost part of the bay (station 1).

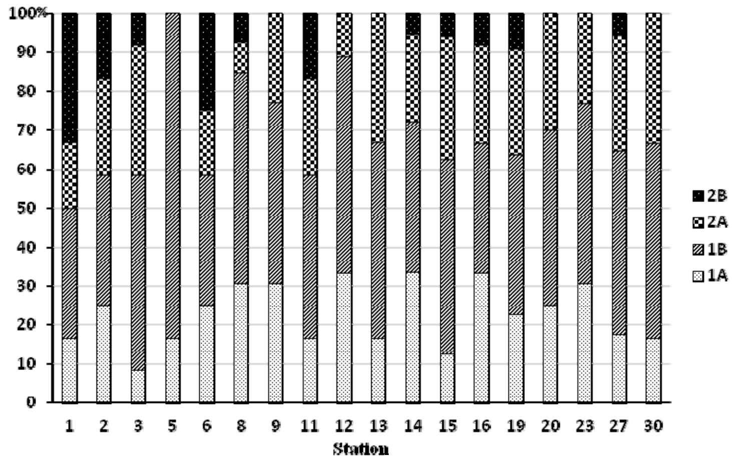

Figure 3. Trophic structure (%) in Sevastopol Bay (May 2013). (1A – selective deposit; 2A – epigrowth feeders; 1B – non-selective deposit feeders; 2B – omnivore/predator).

Non-selective deposit feeders are dominant in all complexes defined by cluster analysis: I–III (Fig. 4). Epigrowth feeders and omnivores/predators were significantly less represented in complexes III and II.

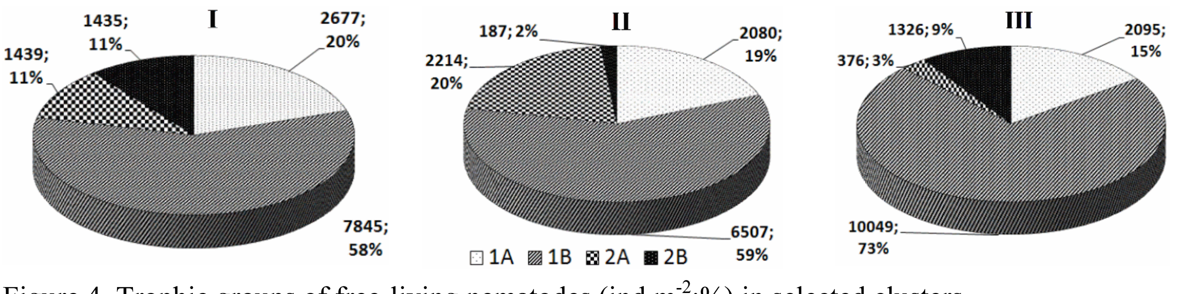

Figure 4. Trophic groups of free-living nematodes (ind.m^{-2};%) in selected clusters.

In 8 out of 18 stations, 6 nematode species (*S. pulchra*; *A. ponticus*; *Parodontophora quadristicha* (Sch.-Stekhoven, 1950); *Sphaerolaimus ostreae* Filip'ev, 1918; *Aponema* sp.1; and *Molgolaimus* sp.1) were found with developmental disorders of paired organs (*amphids*). The identical condition was described previously (Sergeeva, 2003).

A wide range of adaptations of free-living nematodes was detected in the presented collections. These tolerances may explain the specific taxonomic diversity and high numbers of certain species in nematode faunas living under conditions of chronic pollution.

Acknowledgments

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New palynology and microfossil studies of Pleistocene outcrops (Akchagyl) and core samples (Apsheronian, Bakunian, Khazarian, and Khvalynian) in the western, central, and northeastern Caspian Sea region

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Keywords:* *pollen, dinoflagellate cysts, foraminifera, ostracods, magnetostratigraphy, Jeirankechmez, Azerbaijan, Emba delta, Kazakhstan

Introduction

New palynological and microfossil results are presented which together give a more or less continuous stratigraphic record for the Pleistocene in the Caspian Sea region. High density sampling from the Akchagyl Formation (latest Pliocene to Early Pleistocene) at the Jeirankechmez outcrop locality, near Gobustan, Azerbaijan, gives a detailed record of depositional environments in the western onshore region. Data are also presented from drill-core samples in Apsheronian, Bakunian, Khazarian, and Khvalynian sediments from the central offshore area. Lastly, a new palynological record of Khazarian to Khvalynian age is presented from the Emba delta, Kazakhstan.

Methods

More than 200 outcrop and drill-core samples have been studied for palynology, calcareous microfossils, and foraminifera in latest Pliocene to Pleistocene sediments from around the Caspian Sea region. Representative counts were made of *in situ* pollen, spores, dinoflagellate cysts (dinocysts), fungal bodies, and algae. Reworked forms were also recorded. Abundances of ostracods and, where present, foraminifera were also recorded. Stratigraphic assignments are constrained by magnetostratigraphy, regional correlations, Optically Stimulated Luminescence (OSL), and radiocarbon dating.

Results and interpretation

The Akchagyl interval in the Jeirankechmez section contains frequent dinocysts, mainly of restricted marine affinity, which differ significantly in terms of species composition from those occurring in more recent Pleistocene, earlier Holocene, and present-day Caspian Sea sediments. Ostracods previously recorded from the Akchagyl by authors such as Agalarova et al. (1961) and Mandelstam et al. (1962) occur in most samples, but early indications are that *in situ* planktonic and benthonic foraminifera occur only at discrete horizons, suggesting only periodic marine incursions. Several cycles of deposition are visible, with evidence for marine, restricted marine, brackish, and occasionally fully freshwater conditions. Preliminary results suggest that the three-fold stratigraphic subdivision of Mandelstam et al. (1962) based on ostracods can by recognized. Reworked microfossils of varying ages occur throughout the Akchagyl interval. Calibrations to new magnetostratigraphic data are consistent with a latest Pliocene to Early Pleistocene age for the Akchagyl, as indicated by Van Baak et al. (2013) and Forte et al. (2014). The Akchagyl Formation has a varied palynological and microfossil signal in the onshore and offshore western and central Caspian Sea. Both foraminiferal and palynological data show some support for the possibility of a connection to the northern oceans during Akchagyl deposition, as postulated by Forte and Cowgill (2013) and others.

Data from drill-cores taken in the central offshore region reveal a complex sedimentary record for the Pleistocene. Even so, detailed, well-constrained correlations are possible using litho-facies, palynology, micropaleontology, geochemistry, radiocarbon and OSL dating, well-logs, and seismic reconstructions. Dinocysts are dominated by typical Caspian Sea types (see Marret et al., 2004), notably *Impagidinium caspienense*, *Spiniferites cruciformis*, and *Caspidinium rugosum*, whereas pollen assemblages include mixed components of arboreal pollen (AP), non-arboreal pollen (NAP), and reworked types. Intervals with frequent dinocysts invariably also contain rich ostracod assemblages, with *Bacuniella dorsoarcuata*, *Caspiolla* spp., and *Eucythere naphtatscholana* often making up the bulk of the fauna.

Cores from the Emba Delta region, in the northeastern Caspian Sea are dated as late Khazarian, Khvalynian, and Holocene by Verlinden (2009) and Ernens (2010). Four main lithological units are present, each separated by an erosional contact. A palynological record is presented from a 10 m long core, CDSE-12. The basal section is older than 41,500 cal yr BP and contains frequent Pterocysta cruciformis, a low-salinity dinocyst first found commonly in “glacial” stages in the Black Sea (Rochon, 2002). P. cruciformis occurs rarely in the Volga delta region at the present time (Richards et al., 2014) and consistently in the central Caspian region prior to c. 35,000 cal yr BP. The late Khazarian to Khvalynian section in CDSE-12 contains frequent NAP and locally common AP, mainly Pinus (pine) due to long-distance pollen dispersal. The Holocene is less than 1 m thick and is characterized by NAP and dinocysts of restricted marine affinity (high salinity?).

Conclusions

The palynological and microfossil assemblages from the studied areas show that the Akchagyl Formation, at least locally, is primarily a restricted marine interval with only limited fully marine influences. Magnetostratigraphic studies are most likely to indicate a latest Pliocene to Early Pleistocene age for the Akchagyl. Data from the central offshore region reveal the complex nature of the Pleistocene succession. A study of a core from the Emba delta provides the first detailed palynological records from that region and new information about dinocyst distributions. Work is ongoing on all of these studies to interpret the microfossil assemblages fully in terms of their stratigraphic distributions, regional vegetation, paleoclimate, and Caspian Sea level change.

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Meiobenthos structure under different anthropogenic conditions along the coastal zone of SW Crimea (Sevastopol Bays, Black Sea)

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Keywords: taxonomic richness, abundance, distribution, Sevastopol and Kruglaya (Omega) bays

Introduction

Sevastopol includes a number of bays along a waterside region. The bays of Sevastopol are rare natural inland harbors of the Black sea coast of Crimea. Each of these bays has its own character and degree of anthropogenic loading.

Sevastopol Bay is under permanent anthropogenic impact and is regarded as the most technogenically polluted area in the coastal part of Crimea. It is an area of estuarial type with a length of approximately 7 km and an average width of about 1 km. Its average depth is 12 m, and its maximum depth is 22 m. This bay is several hundred meters wide at its seaward part, and it extends inland for about 8 km, providing excellent conditions for ship docking, harboring, and other maritime activities.

After construction in 1976–1977 of a protective breakwater entrance to the bay, the width was narrowed from 940 m to 550 m, which resulted in a twofold reduction in the intensity of water exchange.

The bay is actually a reservoir that receives industrial and domestic waste water and storm water from its catchment area. Increased concentrations of organic carbon in the bottom sediments result in anoxic/sulfide conditions and support the flux of dissolved sulfides from sediments to the bottom layer of water. The long-term industrial, military, and municipal activities were followed by deterioration of the marine environment of the bay and the expansion of bottom areas that became contaminated with various sediment-associated pollutants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals.

Kruglaya (Omega) Bay is a semi-enclosed basin situated in the southwestern part of the Crimean Peninsula. It is part of a larger complex of bays located within the Sevastopol region on the coastline between Cape Chersones and Sevastopol Bay. Kruglaya Bay covers an area of 0.66 km^2 (1.4 km long and 0.9 km wide). Water depths decrease gradually from 17 m at the entrance to 2 m in the innermost part of the bay.

Despite the fact that Kruglaya Bay is located inside the area of Sevastopol city, no industrial facilities are located along its coast. Instead, there are resorts, parks, and apartment buildings found there. Consequently, conditions in Kruglaya Bay could be expected to represent pristine conditions. However, this is not the case. Instead, shallow water depths, relatively weak ventilation, and discharge of municipal waste waters result in local temporal hypoxic conditions at the bottom.

Seasonal changes of meiofauna taxa and meiobenthic response to a variety of hypoxic environments in Sevastopol and Kruglaya bays have been well studied (Sergeeva and Mazlumyan, 2008; Sergeeva et al., 2010; Zaika et al., 2011).

The objective of this report is an assessment of the state of the modern meiobenthos dwelling in the soft bottom sediments. For this meiobenthic survey, areas of Sevastopol and Kruglaya bays were selected that possessed different anthropogenic impacts. The results of the survey of the soft bottoms of these bays are presented.

Methodology

The material was collected at 18 stations distributed over the whole basin of Sevastopol Bay at depths ranging between 1.5–17 m (Fig. 1), and 9 stations in Kruglaya Bay at depths ranging between 1.5–17 m (Fig. 2) in May, 2013.

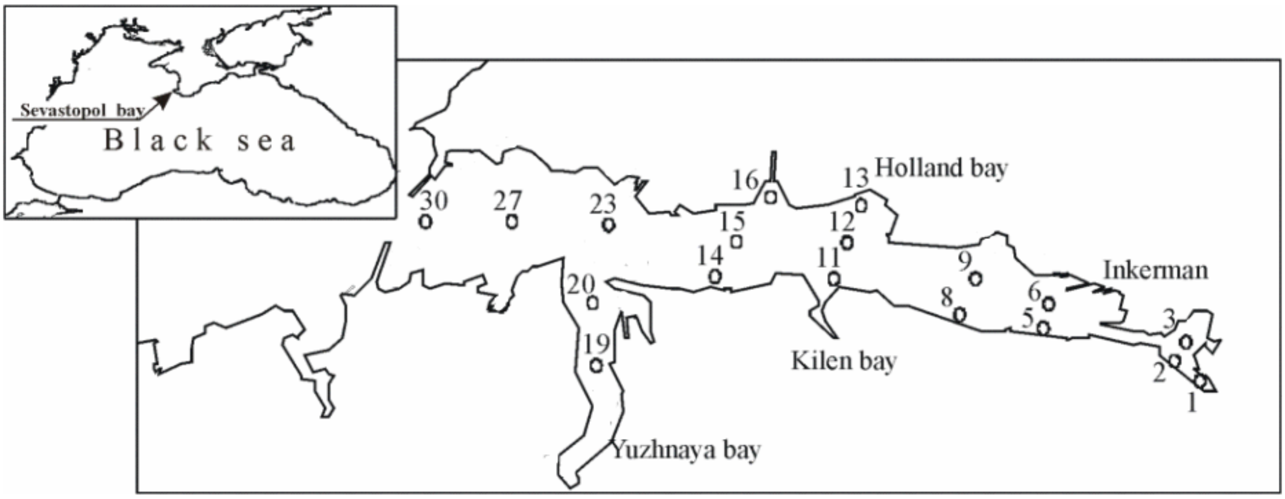


Figure 1. Meiobenthic stations in Sevastopol Bay (May 2013).

For this study of the meiobenthos, two duplicate samples were collected by 18 cm^2 tube from the surface of the bottom monolith lifted by Petersen grab at each station.

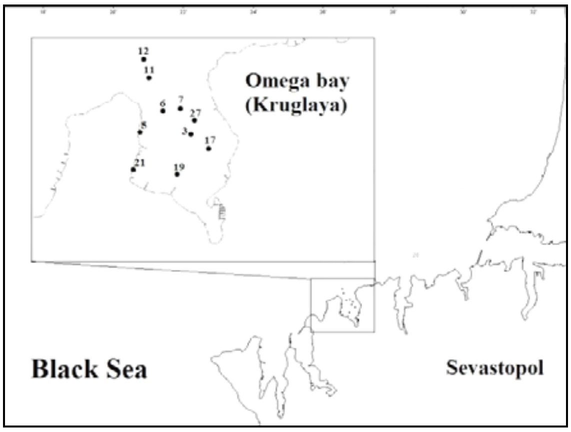


Figure 2. Meiobenthic stations in Kruglaya Bay (May 2013).

Results

Meiobenthos in Sevastopol Bay were represented by 16 taxa: *Gromiida, Ciliophora, Foraminifera, Nematoda, Kinorhyncha, Harpacticoida, Ostracoda, Acari, Tardigrada (eumeiobenthos), and Cnidaria, Polychaeta, Oligochaeta, Turbellaria, Nemertini, Bivalvia*, and *Gastropoda* (pseudomeiobenthos). The dominant groups were *Nematoda, Foraminifera* (soft-shelled forms), *Ciliophora*, and *Harpacticoida*. The abundance of meiobenthos varied from 14,000 to 900,000 ind.m^{-2} depending on the location of the sample stations. Minimum abundance was observed in the inner part of the bay. Along the bay stations, 7–12 groups of meiobenthos are represented (Fig. 3).

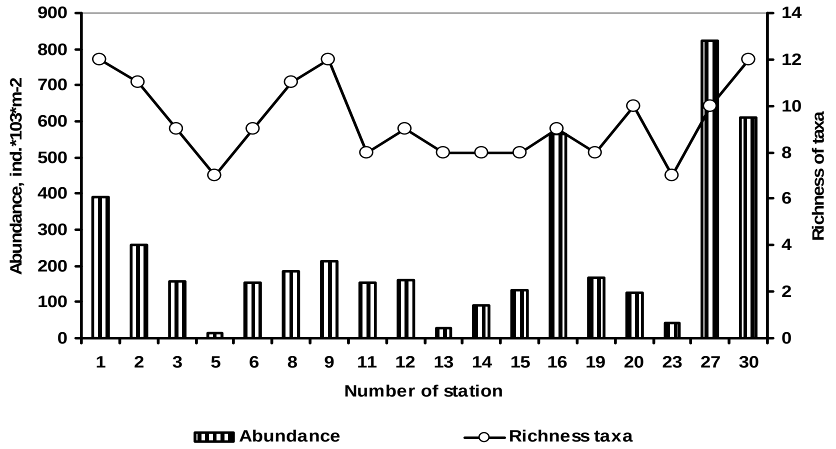
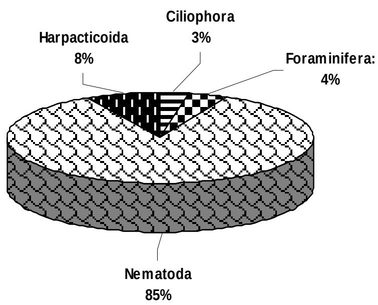


Figure 3. Abundance and taxonomic richness of meiobenthos along stations in Sevastopol Bay (May 2013).

Eumeiobenthos were mostly represented by such groups as Nematoda, Ciliophora, Foraminifera (in particular soft-walled), and Harpacticoida (Fig. 4). Turbellaria and Cnidaria dominated among the Pseudomeiobenthos, in significant proportion were also Polychaeta (Fig. 5).



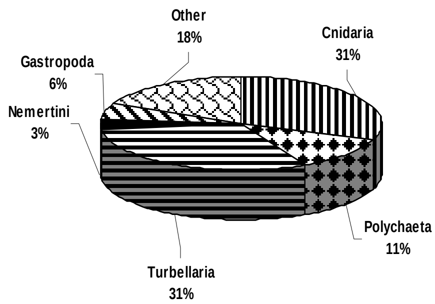


Figure 4. Percentages of main taxa of eumeiobenthos (Sevastopol Bay, May 2013).

Figure 5. Percentages of main taxa of pseudo-meiobenthos (Sevastopol Bay, May 2013).

Meiobenthos in Kruglaya Bay were represented by 17 taxa: Gromiida, Ciliophora, Foraminifera, Nematoda, Kinorhyncha, Harpacticoida, Ostracoda, Acari, Tardigrada, Gastrotricha (eumeiobenthos), and Cnidaria, Polychaeta, Oligochaeta, Turbellaria, Nemertini, Bivalvia, Gastropoda (pseudomeiobenthos). Along the bay stations, 11–17 groups of meiobenthos are represented (Fig. 6).

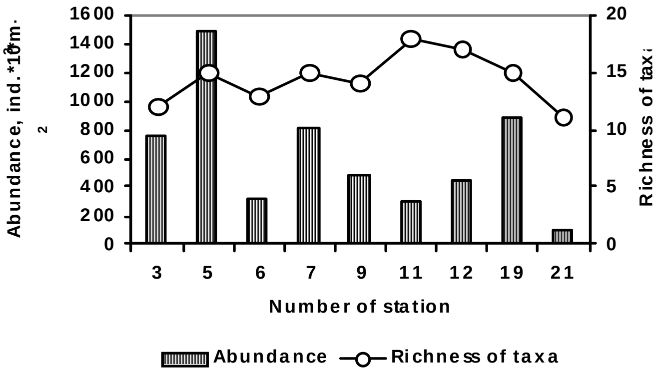


Figure 6. Abundance and taxonomic richness of meiobenthos along the stations in Kruglaya Bay (May 2013).

The dominant groups were Nematoda, Harpacticoida, and Foraminifera (Fig. 7). The abundance of meiobenthos varied from 89,000 to 1,500,000 ind.m^2. The percentage of Polychaeta was 69% of the total pseudomeiobenthos (Fig. 8).

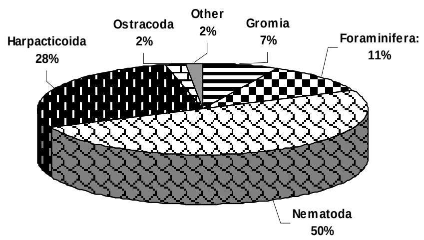


Figure 7. Percentages of main taxa of eumeiobenthos (Kruglaya bay, May 2013).

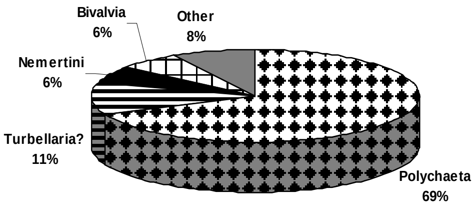


Figure 8. Percenages of main taxa of pseudo meiobenthos (Kruglaya Bay, May 2013).

For the first time in this bay, Gastrotricha were recorded. In general, meiobenthos in Kruglaya Bay were more abundant as compared with Sevastopol Bay. At stations in Kruglaya Bay, the sharp dominance of Nematoda seen in Sevastopol Bay was not noted. In some habitats, the number of Harpacticoida was equal to that of Nematoda. At station 12, Harpacticoida were represented more numerously than Nematoda, which is typical for clean sites with a high oxygen concentration.

Conclusions

Taxonomic variety and a high rate of quantitative development by meiobenthos in both bays testify to the wide adaptive opportunities of bottom fauna under conditions of persistent anthropogenic pollution. But in Omega Bay, which suffers only a recreational load, meiobenthos were represented more abundantly and with a greater number of taxa than in the technogenic pollution of Sevastopol Bay.

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The Allerød in the Northwestern Black Sea region: Climate change and human adaptation

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Keywords: Osokorovka industry, Anetivka industry, paleogeography, occupation system

Introduction

The crucial role of events that took place during the Allerød in the development of environmental conditions and human adaptation in the Northwestern Black Sea region repeatedly take the center of attention among natural scientists and archaeologists. In the region under study, this period traditionally is associated with global climate changes that influenced the dynamic of natural landscapes and caused a transformation in population demography, livelihood and subsistence strategy, and tool production. Basic trends in environmental dynamics across the Northwestern Pontic steppes during the Holocene were initiated at this time, and the main features of human adaptation to post-glacial environments (including basic trends in tool production strategies, subsistence systems, and mobile lifeways) also have their roots during the Allerød.

Peculiarities of paleogeography and human adaptation within the Northwestern Black Sea region allow us to distinguish two provinces of this region: one is connected with the territories lying between the Danube and Pivdenny Bug rivers, and the other is located around the Dnieper Rapids area.

Peculiarities of environment and human adaptation in the territory between the Danube and Pivdennyi Bug rivers

In the climate history of the Northwestern Black Sea region, the Allerød is marked by the final disappearance of glacial conditions. Average temperatures of July were practically the same as now, average annual temperatures varied about 11–12^{o} C (Artyushenko and Turlo, 1989: 85). As a result, the climate is defined as having been slightly colder but wetter than the conditions observed in this region nowadays (Veklich, 1987: 116; Gerasimenko, 1997: 18).

The Allerød landscape lying between the Danube and Pivdennyi Bug rivers generally could be described as one close to meadow steppes. Herb bunchgrass steppes were spread across the upper parts of the relief and the watersheds; halophytic chenopodiaceous vegetation accompanied by wormwood and cereals absolutely dominated there (Artyushenko, 1970: fig. 13). Motley grasses were represented here by mesophilous Compositae (mostly, by Rosaceae and Ranunculaceae); in the Pivdennyi Bug bottomland, typical aquatic vegetation (such as red-mace, water plantain, water lily, etc.) was also represented. Pine and birch forests with alder and spruce spread along the larger rivers and in ravines; smaller proportions of deciduous trees (such as oak, elm, and lime) were also typical for the Pivdennyi Bug lower flow (Artyushenko, 1970: 49, 69; Pashkevich, 1981: 75).

Variability in landscape features traced against the distribution of different species of vegetation correlates with the particularities of faunal assemblages from the region under study. For example, in the third layer of the Volodymyrivka settlement, reindeer, typical representatives of forest fauna, are represented alongside steppe species (horse and steppe marmot) as well as glacial fauna (arctic fox and cave lion) (Chernysh, 1953: 89–95) (Table 1).

Species composition of the basic Northwestern Black Sea region vegetation and fauna let us assume that, due to overall rise in the productivity profile of plant superstructures (i.e., ‘green parts’: leaves, flowers, seeds, stalks, sprouts, etc.), general biomass density per unit of area was considerably higher during the Allerød than during previous phases of the Final Pleistocene. Nevertheless, it was hardly an important environmental phenomenon for the region’s inhabitants, whose subsistence strategy remained bison hunting.

Table 1. Faunal remains from archaeological sites of the Northwestern Steppe region during the Allerød (Chernysh, 1953; Kolosov, 1964).

	Osokorovka industry			Anetivka Industry
	Osokorovka layer 3B	Yamburg	Osokorovka layers 2-3	Volodymyrivka layer 3
Bison (*Bison priscus*)	+	+	+	
Horse (*Equus caballus gmelini*)		+	+	?/3
Reindeer (*Rangifer tarandus*)		+	+	?/19
Fox (*Vulpes vulpes*)		+		
Wolf (*Canis lupus*)			+	
Brown bear (*Ursus arctos*)		+		
Cave lion (*Felis spelaea* Gold.)				1/1
Arctic fox (*Vulpes lagopus*)				?/3
Arctic fox or beaver			+	
Hare (*Lepus* sp.)		+		
Brown hare (*Lepus europaeus*)	+			
Marmot (*Marmota bobac*)				?/11
Hamster (*Citellus citellus*)			+	
Mollusks	+			

Numerator = minimal number of bones (MNB); denominator = minimal number of individuals; + = presence of bones.

Exhausted by extremely intensive exploitation during the Last Glacial Maximum, the Northwestern Pontic steppes declined in suitability for further development during Final Glacial time. Population density in this region considerably decreased; only 1 settlement could be dated to this time span: Volodymyrivka, layer 3, where 4 accumulations of flint artifacts and fauna concentrated around poorly defined thin fireplaces were traced (Chernysh, 1953: 43–51). The flint assemblage of this layer preserves basic features typical of the Late Paleolithic Anetivka flint knapping tradition just as the local subsistence system remained stable and based upon collective hunting for large gregarious game. Nevertheless, one can observe a shift in the selection of hunted species: the bison of previous times was replaced by horse and reindeer, while the population specialized in bison hunting most probably moved to the north (Zaliznyak, 1981: 5–13).

Allerød paleoenvironment and human adaptation in the Dnieper Rapids province

Available evidence gives insufficient information for a detailed reconstruction of the landscape and species composition of vegetation in the Dnieper Rapids province during the Allerød. Based on the general paleogeographic development in this area, it is possible to suggest that the climatic optimum of the Final Glacial was marked by the highest diversity in the resource base of the region, and the highest density of floral and faunal biomass per unit area in the steppe region. This is confirmed also by the presence within archaeological site faunal assemblages of typical steppe inhabitants (bison, horse, and hamster), species connected with semi-closed and closed biotopes (reindeer, bear, and beaver), as well as species with broad adaptive capacities (wolf, fox, and brown hare) (Kolosov, 1964: 42–49) (Table 1).

Such favorable environmental conditions contributed to the highest population concentrations within the Black Sea steppes. The pivotal archaeological site of this region is Osokorovka (layer 3b), which has been interpreted as a seasonal camp. Several roundish ground dwellings forming a circle were found there; their superstructures were woven with willow branches and coated with clay (Sapozhnikov and Sapozhnikova, 2002: 90). Fireplaces, flint artifacts, and faunal remains were recovered outside the structures (Telegin, 1980: 34). The degree of effort expended in the building and maintenance of such constructions allows the assumption that the dwelling structures were occupied during the cold season (Sapozhnikov and Sapozhnikova, 2002: 91). Hunted species and procurement technique did not change in comparison with the previous period; bison, reindeer, horse, and fur-bearing animals still remained the basic prey (Bibikova, 1985: 17–19).

Preservation of traditional subsistence practices and the creation of a relatively complex settlement system and dwelling structures based on them were most probably ensured by substantial intensification in tool production through transition to a technique using geometric inserts (Kolosov, 1964: 42–49). Peculiar high trapezoids, the earliest known among the geometric microliths in the Northwestern Black Sea steppe region, are found in the flint assemblage of Osokorovka, layer 3b; their interpretation as technological and chronological criteria for this period is the subject of sharp discussions (Boriskovskiy and Praslov, 1964; Telegin, 1982; Stanko and Svezhentsev, 1988).

A series of small short-term sites with analogous flint assemblages are found at a limited distance from Osokorovka: Yamburg, Kapustyana Balka, etc. These sites most probably reflect a system of living space exploration peculiar to the Dnieper Rapids area, which implies the existence of a rather stable base settlement that was connected with these short-term camps occupied by mobile groups in accordance with their livelihood needs. Such a settlement system indicates the existence of a concept of proper living space, which needs to be specially marked, exploited, and protected. The earliest collective burial in Eastern Europe, Volosskiy, could date back to the Allerød, and it could be interpreted as a marker for such a proper living space in the real geographic landscape as well as in the social memory of the Osokorovka population, the technological traditions of which most researchers tend to trace back to the local flint knapping techniques of previous times (Vorona Progon I, etc.) (Olenkovs'kiy, 1991: 184; Danilenko, 1955: 56–61).

Conclusions

The dynamics of the demographic and subsistence systems of populations in the Northwestern Black Sea region during the Allerød were caused, in many aspects, by the difficult ecological and demographic situation in this region during the previous period, complicated by the relatively rapid climate changes of the Final Glacial. Average demographic capacity of the Northwestern Pontic steppes decreased, nevertheless, its consequences were different for populations within two basic provinces of the region under study.

Populations in territories lying between the Danube and Pivdennyi Bug rivers under the influences of global climate changes tended to find new territories suitable for continuation of their traditional lifeways. Nevertheless, only part of them moved to the north: the survival of the Anetivka industry without principal transformation of their tool production technique based on retouched blades in the Preboreal and Boreal periods of the Holocene indicates that they managed to find suitable adaptive solutions during the Allerød.

A totally different adaptation was achieved at that time by populations of the Dnieper Rapids province, which was characterized by the most favorable environmental conditions for hunter-gatherers, i.e., climatically mild and rich with field resources. Exploration of this region was based on a peculiar clustered settlement system implying rather stable and long-lasting connections at a base camp with regular movements marked by short-term stops in remote parts of the living territory. The functioning of such a system was enabled by intensification and simplification of tool production techniques through transition to the use of microlithic geometric inserts.

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Population of Mountain Crimea during the Allerød: Human adaptation to global climate change

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Keywords: Shan-Koba industry, Vyshennoe II industry, geometric inserts, subsistence strategy

Introduction

During recent years, the Allerød, or climatic optimum of the Late Glacial, has remained at the center of attention within the framework of discussions about the strategies of human adaptation in the Black Sea basin and the coastal zone development at the Pleistocene-Holocene boundary. Adherents of the so-called Black Sea deluge hypothesis, following W. Ryan and W. Pitman, suggest that the Allerød was a crucial time when the famous 'Flood' took place. Proponents of non-catastrophic changes in the level of the Black Sea after the Last Glacial maximum view the Allerød as the starting point of the gradual sea-level rise. From an archaeological point of view, this discussion is traditionally illustrated by sites of the northwestern and western Pontic region, while cultural remains from the Crimean peninsula seem to be undeservedly ignored. This situation is caused, probably, by geological peculiarities of the coastal zone of Mountain Crimea, which is poorly illustrative for sea-level reconstruction. Nevertheless, its archaeological sites reveal traces of past human migrations, studies of which can highlight important aspects of human adaptation to global climate changes at the Pleistocene-Holocene boundary.

Paleogeography

The relief of Mountain Crimea during the Allerød, traditionally characterized as 'low mountains', and its altitudinal zonality at that time were close to the contemporary ones. The only principal difference is connected with the greater activity of numerous rivers, which during the Allerød were sufficiently free-flowing for big freshwater fish like chub, pikeperch, and roach, while now they can be observed only as temporary water flows and springs. Some researchers stress that the fish skeletons found within Allerød cultural layers are larger and heavier in comparison with modern fish of the same species, confirming in this way the hypothesis that Crimean rivers were much deeper and wider than now (Gromov, 1953: 459–463; Lebedev, 1952: 46–51).

Analysis of microsections of charcoals from a series of archaeological sites indicates the presence of arboreal vegetation (represented mostly by mountain ash and buckthorn) which would have provided habitats of semi-closed biotopes for red deer, brown beer, wild boar, and wild cat (Table 1) (Gammerman, 1934: 70; Bibikova, 1959: 122–124).

The presence of typical steppe inhabitants (horse, saiga, etc.) indicates that open areas (yailla, or mountain pasture), typical for the Mountain Crimea landscape, were still preserved during the Allerød.

The peculiar combination of semi-closed landscapes of mixed forest type (on the lower part of the mountain slopes) originating through a general humidification and warming of the climate with open steppe reflects a general tendency toward diversification of species composition in vegetation and fauna, as well as overall growth of biomass density per unit of area. For studies of human adaptation, this means growth of demographic capacities in the region, making it highly attractive for populations from adjacent territories.

Table 1. Faunal remains from archaeological sites of Mountain Crimea (Allerød).

	Shan-Koba, layer 6	Grotto Skalistyi, layer 3	Buran-Kaya shelter,	Zamil-Koba I, lower layer
Red deer *(Cervus elaphus)*	+	+	+	+
Wild boar *(Sus scrofa)*	+			+
Cattle and bison *(Bos et bison)*			+	
Saiga *(Saiga tatarica)*		+	115/7	+
Horse *(Equus caballus)*			+	
Ass *(Equus asinus)*		+		
Sheep *(Ovis sf. argoloides)*				
Brown bear *(Ursus arctos)*	5/1			
Brown hare *(Lepus europaeus)*	+			
Mountain hare *(Lepus timidus)*			+	2/1
Wolf *(Canis lupus)*	+			+
Wild cat *(Filis sylvestris)*			+	
Roach *(Rutilis rutilis)*	+			
Chub *(Leuciscus cephalus)*	+			
Pikeperch *(Lucioperca lucioperca)*	+			
Mollusks (*Helix*)	+			

Numerator = minimal number of bones (MNB), denominator = minimal number of individuals, + = presence of bones

Human adaptation

Analysis of archaeological site distribution indicates that population density in Mountain Crimea in the Allerød was much higher than it was during the previous period (Fig. 1).

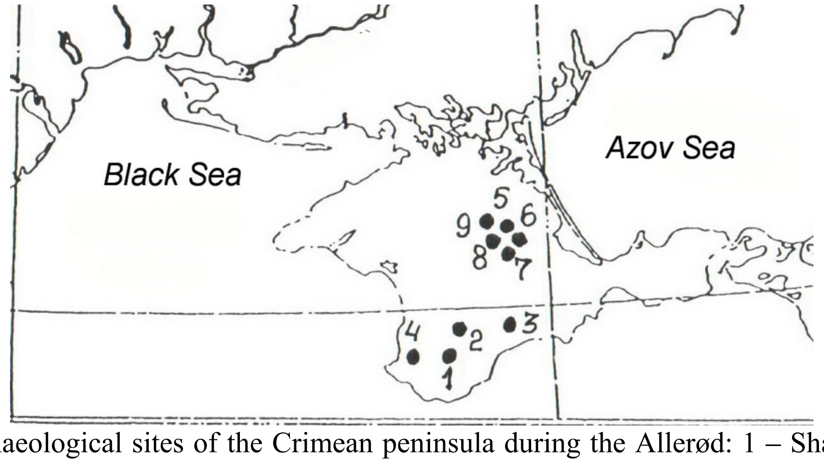

Figure 1. Archaeological sites of the Crimean peninsula during the Allerød: 1 – Shan-Koba, layer 6; 2 – Grotto Skalistyi, layers 3, 3a; 3 – shelter Buran-Kaya; 4 – Zamil-Koba, lower layer; 5 – Vyshenne II; 6 – Biuk-Karasy I; 7 – Biuk-Karasy II; 8 – Biuk-Karasy III; 9 – Biuk-Karasy IV.

Overall growth of population density, nevertheless, was not accompanied by a rise in human group mobility. Most sites of Mountain Crimea are represented by long-term settlements in rock shelters; usually, they consist of dwelling (or living floors), often protected from the wind with the addition of screens, complex fireplaces, storage pits, and other household objects. Analysis of cultural layers from Shan-Koba, Zamil-Koba, Buran-Kaya, and Skalistyi, referred to the Allerød, indicates that their dwelling structures differ by intensity and duration of their occupation, which most probably took place in different seasons of year; nevertheless, all these sites were used repeatedly—groups came back to the site after a certain time, which could be detected in the vertical structure of the cultural deposits (Kraynov, 1938: 12–13; Bader, 1940: 85–88; Kohen, 1994: 143–146; Bibikov et al., 1994: 16–17).

Such a strategy of living space exploitation implied a durable connection with a certain territory maintained by complex household structures that was ensured by the diversification of subsistence strategy, which was based on hunting, fishing, and mollusk utilization.

Faunal assemblages from Crimean archaeological sites contain bones of species adapted to different types of landscape and characterized by different social behavior; it suggests that inhabitants of the Crimean peninsula successfully applied different systems of individual and collective hunting. Most widespread was procurement of non-gregarious game with the help of quick-firing equipment with sighting properties that could be applied for a distance over one hundred meters – a bow with arrows. Most probably, such hunting was realized by small groups consisting of 2–3 hunters. Fish species composition and their skeletal dimensions suggest that fish were acquired through simple individual hunting with the help of javelins or bone harpoons.

Principally new requirements for the tool kit of Crimean populations formed the basis for a transition to a new technique of production based on geometric microlithic inserts. Application of this technique implied the utilization of stardardized multifunctional blanks with minimal secondary processing, which opened the possibility of interchangeable inserts when necessary. This meant people could create a new tool immediately on the spot. This technique was used for production of not only hunting weapon inserts, but also for knives, scrapers, burins, and other categories of the flint inventory. It substantially reduced the time needed for tool kit production, and the overall process of food procurement was intensified.

Discussion

Transition to the inserts technique of flint tool production is today interpreted as one of the basic parameters of the Shan-Koba flint knapping tradition; its origin has been a subject of sharp discussions since the end of 1920s. It was connected with the Western and Central European Paleolithic (G. Bonch-Osmolovskiy, P. Efimenko) as well as with traditions of the Caspian and Mediterranean region (O. Bader, S. Zamyatnin, E. Vekilova, V. Danilenko). Some researchers suggested direct migration of population from the Balkans and the Middle East (D. Telegin, A. Yanevich) or from the Caucasus (S. Bibikov) to the Crimean peninsula. At the same time, other scientists believe it is a local phenomenon based on the industry of Suiren I of the LGM (D. Kraynov, Yu. Kolosov, D. Nuzhnyi).

Environmental interpretation of the Allerød archaeological sites of Mountain Crimea let us suggest that the Shan-Koba flint knapping tradition is of local origin; the new features of the tool kits could be interpreted as a human response to the necessity to transform their procurement system within the new environment.

It should be stressed that application of geometric inserts is typical only for the Shan-Koba flint knapping tradition of the Crimean peninsula. The other tradition, represented by archaeological sites of Vyshenne II type, located in the Crimean foothills and outer steppes, is characterized by the technique of retouched blades, the closest analogies to which can be found in the previous stages of the Late Paleolithic in the Middle Dniester region with the Molodove industry (Stanko, 1997: 128).

Conclusions

The Allerød in Mountain Crimea is marked by the transformation of the environment, human subsistence strategy, and tool production techniques of the local Late Paleolithic population that resulted in the origin of the peculiar Shan-Koba flint knapping tradition. Its model of adaptation is characterized by stable long-lasting connections with the first and second mountain ridge living space, which is traced archaeologically by the presence of long-term cave dwellings and diversified household structures. The high demographic capacity of the region and the exploration of geometric inserts as a technique of tool kit production were the crucial basics of such a mode of life and subsistence strategy.

At the same time, further development of the non-geometric Vyshenne II industry resulted from direct migration of the Middle Dniester population to the Crimean steppe and foothills. This not only reflects the fact that such direct contacts and movements across the Black Sea shelf were still possible during the Allerød, but it also indicates that the migrants could survive in their new territory without principal transformation of their tool production strategy and other components of their subsistence strategy.

Taken together, both aspects of cultural exploitation of the Crimean peninsula during the Allerød raise serious doubt about the hypothesis of catastrophic consequences for the human population due to the Black Sea rise at that time.

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Gradients of salinity in the Sea of Azov and the influence of salinity on recent bottom sediment composition

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Keywords: Syvash Lagoon, Arabat Spit, chemical elements, bottom microbiota, nitrogen-fixing cyanobacteria

Introduction

The Sea of Azov (Palus Maeotis) is a semi-enclosed sea in the Ponto-Caspian system. It is shallower than 12 m. One of the peculiarities of the coastal morphology along the northern Sea of Azov is accumulative sand spits, and the Arabat Spit is the most interesting among them (Fig. 1). The Arabat Spit stretches for more than 100 km along the western edge of the sea and separates the Sea of Azov from the hypersaline water of the Syvash Lagoon. Chemical composition of the Syvash Lagoon water and bottom sediments are formed under the influence of numerous hypersaline lakes, which are located on the Crimean coast (Kostyushin, 2000).

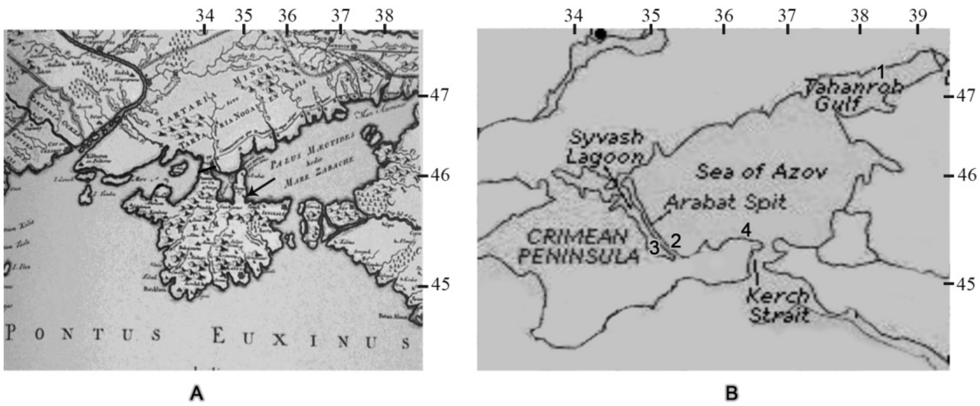

Figure 1. The Crimean peninsula and the Sea of Azov with the Arabat Spit (arrows indicate its location); (A) this map was compiled by the engineer Renome in 1737 (Kovalevskii, 1920); (B) recent map of the Sea of Azov and location of the sampling stations.

Recent bottom sediments in various areas of the Sea of Azov differ greatly on the basis of genetic, mechanical, and qualitative compositions. The main factors affecting the composition of water and bottom sediments are the influence of the Kuban and Don rivers (Tahanroh Gulf), the Kerch Strait (the Black Sea flow), atmospheric aerosols and rainfall, and the Crimean salt lakes (Fig. 1, B). Bottom sediments are the main targets for studying the geologic history of the seas. The Sea of Azov can be a natural model for understanding the influence of physical, chemical, and biological processes on substances deposited within sediments.

The objective of this work is to estimate the effect of salinity on the distribution of some chemical elements and microbiota in coastal bottom sediments of the Sea of Azov. This paper presents both the results of experimental work and the analysis of published data (Rjabinin and Shibaeva, 2012).

Methodology

Experimental work was carried out with bottom sediment sampling by divers during the summer and autumn seasons of 2010 to 2013 (points 2 and 3, 4). Salinity was measured in wet sediment samples using water from the water-sediment interface by means of a "Sansi-5" (Hitachi) standardized to the

Reference-Composition Salinity Scale (Intergovernmental Oceanographic Commission, 2010). In the dry sediment samples, the content of some chemical elements was studied using neutron-activation and the technogenic radionuclides Cs-137 and Sr-90 by γ-spectrophotometry.

Results

The Sea of Azov bottom sediments are represented by mussel pelitic silts. Bottom sediments at points 2 and 3 (Arabat Spit) are of biological origin. These are more than 50% shell sand and detritus. The coastal zone of the Arabat Spit is characterized by abrasion processes. As a result of the mechanical energy of sea waves, different compositions of lithosphere substance with mollusk shells are formed (Fig. 2).

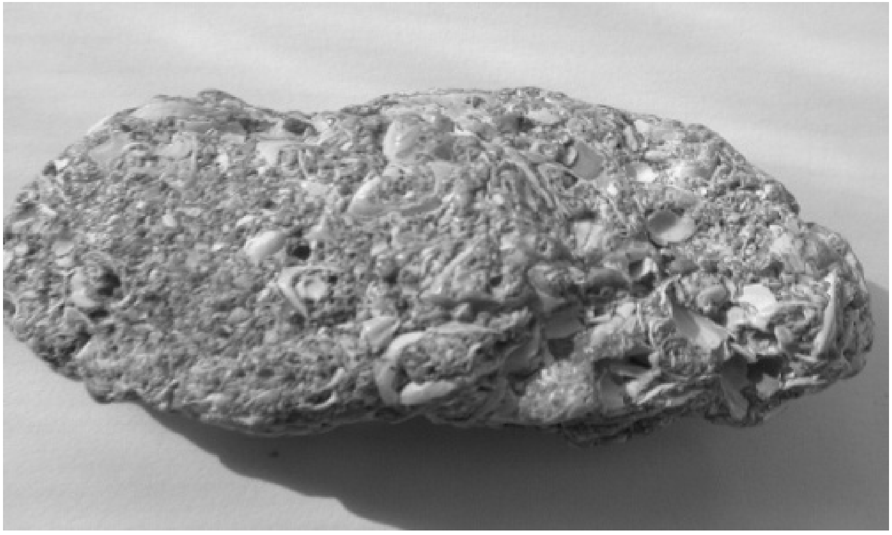

Figure 2. Silica-carbonate formation found on the eastern coast of the Arabat Spit. It is possible to see small shells of mollusks which lie convex side down.

In Tahanroh Gulf (point 1), muddy sediments dominate under the influence of the Don River flow. Syvash Lagoon is a shallow bay on the Sea of Azov (Fig. 1, B). This lagoon is wetland, like the Danube Delta (Kostyushin, 2000). The periodic appearance of hydrogen sulfide has been noted in Syvash's near bottom water (Sovga and Chjurova, 2013). The surface hydrographic conditions in the Azov Sea are characterized by east-west gradients of salinity (increase). Physico-chemical migration and precipitation, and biological cycling of chemical elements are dependent upon salinity and sorption/desorption processes between the aqueous phase and the solid suspension. Table 1 gives comparative data on the chemical composition of recent sediments in different coastal zones of the sea.

Table 1. Content of some chemical elements in bottom sediments of the Sea of Azov (data from 2010 to 2013).

Hydrochemical parameter	Location of the sampling stations			
	Point 1 S 46°40′ – 46°50′ E 37°50′ – 38°00′	Point 2 S 45°20′ – 45°25′ E 35°25′ – 35°30′	Point 3 S 45°15′ – 45°20′ E 35°20′ – 35°25′	Point 4 S 45°30′ – 45°35′ E 35 °25′ – 35°30′
Bottom water – sediment interface				
Salinity,‰	2.80 – 9.60	11.00 – 12.60	36.00 – 45.50	11.5 – 14.00
pH	8.35– 8. °90	7.40 – 8.30	8.20 – 8.65	7.75 – 8.25
Si, mg per liter	0.88 – 2.15	0.70 – 0.15	0.22 – 1.00	0.44 – 1.70
Metallic elements in bottom sediments, $n \cdot 10^{-2}$% (top layer 5–25 cm deep)				
Ni	0.4320	0.7190	0.6940	0.9660
Cu	0.2250	0.2650	0.4010	0.3240
Sr	5.0000	1.0000	23.0000	16.0000
Cd	0.0015	0.0015	0.0023	0.0016
Pb	0.1780	0.1880	0.3040	0.2250
Fe,%	1.2000	1.1000	1.4000	1.3000

A positive correlation is frequently observed between the concentrations of Cu, Cd, Sr, and Pb in bottom sediments and levels of salinity. We noted an increase the content of Fe, Cu, and Pb (halophilic elements) in Syvash Lagoon. Cu and Fe can react with reduced sulphur through processes in the formation of sulphides. Fe in bottom deposits is less mobile at high values of salinity. Unlike these metals, the content of dissolved silicon, which passes into bottom sediments as a result of biological cycles, is minimal in Syvash Lagoon.

Rjabinin and Shibaeva (2012) noted that long-lived natural and technogenic radionuclides (Cs-137 and Sr-90) can penetrate into sea water with atmospheric aerosols. Maximum radionuclide level found (at point 3) was more than 30 Bq per kilogram of sediment, and the minimum was less than 10 Bq per kilogram of sediment (at point 4).

Conditions in Syvash Lagoon are favorable for the development of phototrophic sulphur bacteria, and purple sulphur bacteria were found in the sediment samples. These bacteria were characterized by high activity and sulphate reduction. Nitrogen-fixing cyanobacteria assemblages are a dominant fraction of the bottom microbiota in the lagoon.

Conclusions

Changes in salinity are related to significant differences in mineral and organic components of bottom sediments in Tahanroh Gulf and the southwestern shelf of the Sea of Azov at Syvash Lagoon. It has been noted that environmental conditions in the shallow Syvash Lagoon are similar to conditions on Earth in Archaean and Proterozoic times (Rozanov, 1999). Therefore, work with recent sediments of the Sea of Azov is useful for interpretation of the varying environmental conditions that have characterized the evolution of the Mediterranean to Caspian Sea system over a long period.

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Age of the Khvalynian deposits of the northern Caspian Sea according to AMS ^{14}C dating

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Keywords: Northern Caspian Sea, cores, deposits, radiocarbon method, AMS dating

Introduction

The Khvalynian transgression was a significant sea-level rise up to 50 m asl, and well-preserved coastlines allow for reliable evaluation of the area and size of the Khvalynian basin. Khvalynian sediments are the most extensive of all Neopleistocene sediments in the Caspian Sea area. They are differentiated into Lower (hv_1) and Upper Khvalynian (hv_2) on the basis of the geomorphological position of the sediments and the peculiarities of taxonomic composition of the Khvalynian mollusks. Sediments within the absolute depth interval of 50–0 m asl are attributed to the $hv_{1,}$ and lower deposits (0 to –19 m) are attributed to the hv_2. Khvalynian deposits have yielded numerous absolute age estimations by radiocarbon (^{14}C), uranium-thorium ($^{230}Th/^{234}U$), and thermoluminescence (TL) dating. Based mostly on TL dates, Rychagov (1997) estimated the age of the hv_1 deposits as 70–40 ka, and the age of the hv_2 deposits as 20–10 ky. An opposing point of view based on ^{14}C and $^{230}Th/^{234}U$ dating was proposed by (Kvasov, 1975; Svitoch and Yanina, 1997; Arslanov et al., 2013). New data on the age of the Khvalynian deposits came from samples obtained within marine boreholes in the northern Caspian Sea, and the dates were initially determined by the ^{14}C scintillation method (Bezrodnykh et al., 2004; Arslanov et al., 2013). According to these data, the base of the hv_1 horizon would be dated at 30–32 ka, and the base of the hv_2 horizon at 15–16 ka. In recent years, new data on the age of the Khvalynian deposits along the Caspian Sea coasts has emerged using the AMS method (Tudryn et al., 2013). These authors defend a "young" age for the Khvalynian deposits: 16–9 ka. The aim of our investigation is to present a new dating of the Khvalynian deposits from the marine cores as conducted by the ^{14}C AMS method.

Material and methods

We carried out biostratigraphic and geochronologic studies of the borehole cores from the northern Caspian Sea. For dating, we sampled mainly shells of the index-genus *Didacna.* Dating was conducted using the ^{14}C AMS method at the Lawrence Livermore National Laboratory (USA). When given without decimal places, ^{13}C values are assumed values. Values measured for the material itself are given with a single decimal place. The quoted age is in radiocarbon years using the Libby half life of 5568 years and following the conventions. The radiocarbon concentration is given as fraction Modern, $D^{14}C$, and conventional radiocarbon age. Sample preparation backgrounds have been subtracted, based on measurements of samples of ^{14}C-free calcite. Background was scaled relative to sample size.

Results

Results of age determinations for Kvalynian mollusks are given in the Table. The dates testify to a more ancient age (up to 56 thousand years) for Khvalynian deposits than was previously supposed based on the radiocarbon method. The dates differ from those ^{14}C dates obtained by both scintillation and ^{14}C AMS method for Khvalynian deposits from the Caspian coasts. Dates of these coastal deposits are significantly younger. AMS dates for the Khvalynian deposits of the marine core also differ and from the dates made by the ^{14}C scintillation method for the same deposits. In this case, the AMS dates are also more ancient. We don't know the cause. It is possible to assume that dates of deposits of coasts are rejuvenated as a result of pollution of thin Khvalynian shells by young carbon. But why AMS dates are more ancient remains a question for us.

Table. Age determinations for Khvalynian mollusks by the ^{14}C AMS method

Laboratory number	Borehole (core interval, m)	$\sigma^{13}C$	Modern fraction	$D^{14}C$	Species of mollusks	^{14}C years
Area Khazri						
CAMS 159399	IGS-3 (5.20–5.35)	0	0.0466± 0.0004	–953.4±0.4	*D. praetrigo-noides*	24630±80
CAMS 159403	IGS-3 (5.20–5.35)	0	0.0462± 0.0004	–953.8±0,4	*D. parallella*	24700±80
CAMS 162564	IGS-3 (10.30–11.05)	0	0.0007	–999.3	*D. ebersini*	>51200
CAMS 162566	IGS-3 (28.60–28.85)	0	0.0007	–999.3	*D. cristata*	>51200
CAMS 159400	IGS-3 (35.70–35.90)	0	0.0039± 0.0004	–996.1±0.4	*D. subcatillus*	44560±850
Area Rakushechnaya						
CAMS 162561	IGS-1 (28.40–28.60)	0	0.0035	–996.5	*D. ebersini*	45400±1200
CAMS 162569	IGS-5 (38.70–38.75)	0	0.0033	–996.7	*D. subcatillus*	46000±1300
Area Filanovskogo						
CAMS 162563	IGS-1 (38.00–38.05)	0	0.0030	–997.0	*Micromelania caspia*	46600±1400
Area Korchagina						
CAMS 163751	ISG-5 (7.00–7.54)	0	0.0276	–972.4	*D. ebersini*	28830±150
CAMS 163752	ISG-5 (12.31–12.34)	0	0.0010	–999.0	*D. ebersini*	55600±3000
CAMS 163753	ISG-2 (17.45–17.80)	0	0.0002	–999.8	*D. subcatillus*	>55700
CAMS 163754	ISG-2 (21.40–21.50)	0	0.0009	–999.1	*D. subcatillus*	56300±3300

Conclusions

For the first time, dating of the Khvalynian deposits from boreholes in the northern Caspian Sea has been conducted using the ^{14}C AMS method. The obtained dates in the range of 25–56 thousand years are documentation of more ancient ages for the beginning of the Khvalynian transgression, and of a significantly longer duration for the Khvalynian epoch. These new data allow the correlation of most of the Khvalynian epoch of the Caspian Sea with the Middle Valday interstadial events of the East European Plain.

Acknowledgments

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History of the Great Caspian Sea

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Keywords: Caspian Sea, Akchagylian, Apsheronian, Caspian (Quaternary) transgressive epochs

During the last 3 million years, during the late Pliocene and Pleistocene, a huge freshened marine and brackish-water basin—the Great Caspian Sea—existed in the inner continental region of Eurasia within the vast Caspian depression and surrounding lowlands. This water basin represented the final evolutionary stage of the Eastern Paratethys, which started at the end of the Early Miocene when the Paratethys subdivided into western and eastern basins. The history of the Great Caspian Sea consists of three main transgressive epochs: the Akchagylian, Apsheronian, and Caspian (Quaternary, Pleistocene), separated by the Domashkino and Turkyan regressions (Fedorov, 1978; Rychagov, 1997; Svitoch and Yanina, 1997; Nevesskaya, 2007; Svitoch et al., 2010; Svitoch, 2012; among many others).

The Akchagylian transgression formed the biggest and the most long-lasting Great Caspian Sea basin. Its area was nearly three times (2.7) as large as the modern Caspian Sea, and the duration of its existence was 1.5 million years. The sea level probably reached 100 m absolute height, and the depth of the basin exceeded 500 m. The end of the Akchagylian transgression (epoch) was caused by the cessation of marine input. The basin was considerably freshened, the salt composition of its waters changed, and marine malacofauna became extinct. Complete extinction occurred during the Domashkino regression that separated the late Pliocene basins of the Great Caspian Sea.

The Apsheronian transgression occurred during the interval of 1.8–0.7 million years ago. The areal extent of this transgressive basin was 1.16 times smaller than that of the Akchagylian, but 2.2 times greater than the modern Caspian Sea. During the transgression, maximum sea level probably reached 60–80 m in absolute elevation. The Apsheronian epoch ended at the end of the Pliocene with the onset of the Turkyan regression, which was the deepest and longest in the history of the Great Caspian Sea. Considerable freshening of the Apsheronian basin started in the second half of its final stage, together with the disappearance of the brackish-water fauna that became almost completely extinct by the onset of the Pleistocene epoch.

The Caspian (Quaternary) epoch is the long final stage in the evolution of the Quaternary basins of the Great Caspian Sea, roughly corresponding to the last 0.8 million years. Unlike the Pliocene basins of the Great Caspian Sea, this epoch is characterized by sharp sea-level oscillations in different directions as well as changes in the areal extent of the basins. In fact, it represents a system of transgressive rhythms of different amplitudes (epochs, stages) divided by deep regressions. During maximum transgressions, sea level exceeded its modern position by 80 m, and the area of the sea was 1.2 times bigger than at present. During regressive epochs, sea level dropped below its modern position by 100 m, the shelf was exposed, and the area of the sea diminished by 1/3 its modern size. These changes are reflected in the structure of the Quaternary sedimenary sequence, which represents a kind of "shortcake" of marine, fluvial/lacustrine, and rarer subaerial deposits. The composite Quaternary sediment section is dominated by the Baku, Khazarian, and Khvalynian transgressive beds, with a thin cover of New Caspian deposits. In their areal extent, the distribution of Quaternary marine sediments resembles the Apsheronian basin. They occupied the whole Near Caspian Lowland, the mouths of large river valleys of the Mid-Volga River region, the depressions of the Mangyshlak, Krasnovodsk Peninsula, Kura, Western Turkmenian, and Northern Iran (Cis-Elburz) lowlands, the Caucasian coast, the Manych depression, and the Sea of Azov.

Lithofacies composition of marine sediments varies from fine muds and clays of the deep-water facies to pebble beds of the piedmont shallow-water facies. Unlike pre-Pleistocene deposits, diagenetic transformation of sediments is different and varies from semi-fluid dispersed muds of the Caspian Sea depressions to dense, lithified, detrital limestones and conglomerates of the Turkmenian and Azerbaijan coasts. Diverse epicontinental facies are the most common. Frequent lithological changes along the sediment sequence give evidence for a diversity of hydrological conditions and the presence of exotic facies, which include syrt deposits in the Northern Near Caspian region, late Khvalynian knoll sands in the nearshore regions close to the river mouths of the Northern Near Caspian region, and chocolate clays in the estuaries of the paleo-Volga and paleo-Ural rivers. Sediment composition of the main Quaternary transgressive beds is different. Sediments of Baku age are generally more fine-grained and have substantial thickness (up to 500 m and more). Khazarian sediments are more coarse-grained; they are often lithified and correspond to dynamic conditions of nearshore regions and beaches. Khvalynian and New Caspian deposits are characterized by a sandy-clayey composition and the presence of exotic facies of chocolate clays and Baer sands. Numerous breaks in marine sedimentation in the Quaternary sediment sequence are reflected by erosional surfaces and the presence of diverse terrestrial formations. The latter are mainly fluvial and lacustrine in origin (the Upper Ushtal' Formation, alluvium of the Vened and Krivichi Formations, liman-flood plain Singil' beds, the Chernyi Yar alluvium, the Atel' Formation, the Mangyshlak beds). Rarely, they are represented by subaerial deposits (automorphous soils, carbonate loamy sands of the upper Syrt Formation).

Marine Quaternary Caspian Sea deposits contain different fossils: mollusks, ostracods, foraminifers, diatoms, pollen, and spores. Analysis of the distribution of fossil molluscan assemblages, primarily mollusks of the *Didacna* Eichw. genus, is the most important tool for stratigraphic subdivision and paleogeographical reconstructions. Caspian *Didacna*(s) are represented by 74 species and subspecies originating with Apsheronian and Gurian (?) relics. They form three related groups: "*catillus*," "*crassa*," and "*trigonoides*," restricted to certain basins and sediment sequences. For instance, the Baku substage is characterized by mollusks of the "*catillus*" and "*crassa*" groups, the Khazarian stage—by "*crassa*" and "*trigonoides*" groups, the Khvalynian stage—by "*catillus*" and "*trigonoides*" groups, and the New Caspian stage—by "*crassa*" and "*trigonoides*" groups. The combination of abundant reference fossil groups and clear lithological contacts between sediment layers allows for a detailed stratigraphic subdivision of Quaternary sediment sequences that is hardly available in other regions. This is especially true for the Lower Volga River region, where Quaternary sediments are also rich in mammalian remains of the Singil', Khazarian, and Paleolithic complexes. Thus, the Lower Volga River region was proposed as a stratotype region for the temperate zone of Eurasia since it meets all requirements of the IGSN for stratotypes, where completeness of the sequence is accompanied by clearly stratified beds, abundance of fossil remains, suitable geographic position, presence of excellent exposures, and high level of analytical geological research by different methods.

Study of the distribution of different molluscan groups along the sediment sequence has demonstrated that the paleosalinity of the Pleistocene Caspian Sea was typical of large, closed, mixohaline basins, i.e., rather low, with a high content of heavy sulphate and carbonate salts of the alkaline earth metals (Ca and Mg) and low concentration of K^{+1} and Cl^{-1} ions. Salinity of the Middle and Southern Caspian Sea during transgressive and regressive epochs varied slightly and average salinity was about 13‰. Therefore, it was close to the paleosalinity of the Apsheronian basin. During major transgressions (Baku, Khazarian), paleosalinity increased slightly toward their end as evidenced by the growing representation of mollusks belonging to the "*crassa*" group. Marginal parts of the sea experienced considerable salinity variations. Interestingly, during regressions, salinity in the shallow-water parts of the Caspian Sea decreased, whereas during transgressive epochs, when the basin's water volume increased by 2 times and more, salinity increased by 6–7‰ due to salt extraction from the older marine deposits, flooded salt domes, and salt migration from other parts of the sea.

The climate of the Caspian Sea area during the Pleistocene strongly differed from that of the late Pliocene. In the Pleistocene, ice sheets periodically penetrated the Russian Plain, and mountain glaciers existed in the Urals, Caucasus, Elburz, and Kopetdag. High marine terraces suggest the coastal parts of mountain ridges were elevated by up to 200 m and more, while the Middle and Southern Caspian Sea depressions continued to descend. As a whole, the biggest Pleistocene transgressions of the Caspian Sea were correlative with cold epochs on the Russian Plain. In general, the Don glaciation corresponded to the Baku transgression, the early Khazarian transgression correlated with the post-Likhvin (Dnieper) cooling, and the early Khvalynian transgression correlated with the late Valdai (Würm) glaciation. However, in the history of the Caspian Sea, there are indications not only of “cold”, but also “warm” transgressions. The latter are represented by the Urundzhik, late Khazarian, and New Caspian transgressions. These transgressions are distinguished by the dominance of the thermophilic “*crassa*” group of *Didacna*, restricted areal extent, short duration, and inconsiderable sea-level rise. All of them are correlative with interglacial epochs on the Russian Plain.

The Pleistocene basin, like the older basins of the Great Caspian Sea, was a self-regulating system. However, unlike the older basins, the maximum extent of the Pleistocene Caspian Sea was controlled by the height of the Manych sill that regulated the outflow of Caspian Sea water and not by the increasing riverine sediment discharge, decreasing evaporation, and neotectonic development. The minimal areal extent of the Pleistocene basins was determined not only by the decreasing water balance, but also by the water capacity of the depression. Other states of the basin depended on the water balance.

Conclusions: (1) The basins of the Great Caspian Sea represent a system of large continental water bodies that evolved within a single territory. (2) The unity of their development lies in the gradual and continuous change from a semi-closed freshened-marine Akchagylian basin to an isolated brackish-water Apsheronian sea, and then to a degrading brackish- and freshened- brackish-water Quaternary Caspian Sea. (3) The unity of the Great Caspian Sea basins is determined by the composition and relationship between its molluscan faunas. All Apsheronian bivalves originate from Akchagylian Cardiidae and Dreissenidae. Caspian mollusks have their ancestors among Apsheronian *Hypanis, Dreissena*, and probably *Didacnoides*. (4) Every basin in the history of the Great Caspian Sea differed from each other, thus reflecting specific paleoenvironmental situations. (5) The Akchagylian basin was formed due to the flooding of the system of the Caspian and adjacent depressions by oceanic (Mediterranean) waters. The Apsheronian basin was a relic and completely isolated brackish-water basin that formed after the cessation of seawater input in late Akchagylian time and subsequent freshening during the Domashkino regression. The Caspian Sea developed as a result of the degradation and freshening of the brackish-water Apsheronian basin during the Turkyan epoch. It was characterized by sharp sea-level oscillations and areal extent. (6) The faunas of the basins, although being closely related, differ in their dependence upon past environmental and hydrological conditions. (7) The differences between the various basins of the Great Caspian Sea were quite diverse. Between the Akchagylian and Apsheronian basins, the differences were in the size of the basins, their salinity, and the composition of inhabitants; between the Apsheronian and Caspian basins, the differences were between sea-level oscillation rhythms, the character of sedimentation and sediment origin, and the composition of the mollusks. Naturally, the biggest differences were observed between the initial (Akchagylian) and final (Quaternary) epochs. These included differences between the origin of the basins, their size, duration, hydrological conditions, faunas, sea-level oscillation rhythms, and sedimentation character. The last stage in the Great Caspian Sea evolution—i.e., its present stage—clearly reveals the degradation of the large marine basin that formed at the end of the late Pliocene, existed for the last 3 million years, and ended in the modern closed basin. This is primarily manifested in the enhancement of regressive tendencies at different hierarchical levels with sharp sea-level falls and exposures of the Caspian Sea shelf. This undoubtedly resulted from the climate and Pleistocene hydrological conditions in the Caspian Sea and adjacent regions of the Eurasian continent.

The modern state of the Caspian Sea with the perspective of its long history of oscillations could be referred to as the post-Khvalynian regressive epoch. It is the end of the New Caspian transgressive stage complicated by (1) a regressive oscillation that finished with a slight sea-level rise at the end of the 20th century and (2) the recently established unstable state. From this, it might be possible to predict a continuous regressive state for the sea, possibly for hundreds of years. At the same time, similar to the late Holocene, sea level will experience oscillations of small-amplitude (several meters) in different directions.

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From lake to sea: The malacological signature of the inundation

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Introduction

The history of the postglacial marine flooding of the Black Sea from the Mediterranean Sea is well documented by drastic faunal turnovers, although still highly controversial in details regarding tempo and mode (Ryan et al., 2003; Yanko-Hombach et al., 2007; Giosan et al., 2009; and many others). The paleobiological legacy found in the Black Sea sedimentary record admirably documents that this basin was a lacustrine environment of substantial size (the Late Neoeuxinian Lake: Yanko-Hombach et al., 2007, with references therein) that somehow abruptly turned into marine conditions as Mediterranean sea level reached up enough to breach the Dardanelles and Bosphorus straits (e.g., Major et al., 2006; Lericolais et al., 2011; Nicolas et al., 2011; Soulet et al., 2011).

Sedimentary cores collected in the northwestern Black Sea in the frame of the BLASON project contain an excellent malacological documentation of pre-flood lacustrine, and syn- and post-flood marine environments. In particular, cores BLK98-15, BLVK-5, and BLKS-26 host relatively diverse mollusk assemblages.

The mollusk faunas in the cores

The Late Neoeuxinian Lake

The following mollusks have been identified that pertain to this situation: *Theodoxus fluviatilis* (Linnaeus, 1758); *Theodoxus* sp.; *Micromelania* cf. *lincta* Milashewich, 1908; *Clathrocaspia pallasi* (Dybowski, 1888); *Clessiniola variabilis* (Eichwald, 1841); *Monodacna* cf. *pontica* Eichwald, 1838; *Monodacna* cf. *colorata* (Eichwald, 1829); *Dreissena polymorpha* (Pallas, 1771); *Dreissena caspia* Eichwald, 1855; and *Dreissena bugensis* Andrusov, 1897.

The mollusks are mainly Pontocaspian taxa known from freshwater to anomalohaline habitats in the Black and Caspian Seas. A few (e.g., *M. lincta*, *C. variabilis*, *M. pontica*, and *D. bugensis*) are also known from the pre-flooding records in the Marmara Sea (Taviani et al., in press), or present a wide geographic range (e.g., *D. polymorpha*).

The marine fauna

The following Mediterranean mollusks mark the marine ingression and establishment of marine conditions in the Black Sea that abruptly cancelled the previous mollusk fauna: *Pusillina lineolata* (Michaud, 1832); *Bittium* cf. *reticulatum* (Da Costa, 1778); *Bittium submamillatum* (De Reyneval & Ponzi, 1854); *Calyptraea chinensis* (Linné, 1758); *Marshallora adversa* (Montagu, 1803); *Cerithiopsis* sp.; *Trophonopsis breviatus* (Jeffreys, 1882); *Retusa truncatula* (Bruguiere, 1792); *Mytilus galloprovincialis* (Lamarck, 1819); *Modiolula phaseolina* (Philippi, 1844); *Kurtiella bidentata* (Montagu, 1803); *Spisula subtruncata* (Da Costa, 1778); *Abra segmentum* (Recluz, 1843); *Papillicardium papillosum* (Poli, 1791); and *Parvicardium exiguum* (Gmelin, 1791).

Remarks

Trophonopsis breviatus, accepted as a valid species although on morphological arguments only, was once considered a Black Sea endemic. Interestingly, our Black Sea core record contains shells of this gastropod in sediments immediately following the early *Mytilus* colonization. In consideration that the arrival of marine benthic mollusks in the Black Sea is a quite recent situation, it may be hypothesized that either *T. breviatus* is simply an ecological form of the widespread Mediterranean *T. muricatus* or that it is an eastern Mediterranean species (see, for example, Demir, 2003) that entered the Black Sea with the latest inundation. More in general, it has been long supposed that the Black Sea mollusk fauna includes quite a few endemic species and a number of local forms (e.g., Milashewich, 1916; Grossu, 1956). This number has lately been considerably scaled down, and many such Black Sea species are by now synonymous with current Mediterranean taxa (e.g., Micu, 2004). The on-going European Union Project CoCoNet (Towards COast to COast NETworks of marine protected areas) will further clarify this aspect by adding a bio-molecular approach to selected Mediterranean/Black Sea paired taxa. In principle, this could provide an independent view on timing of their geographic separation through the level of genetic distance achieved thus far, then to be checked versus the reconstructed timing of Black Sea inundation.

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Assessment of the *Mytilus galloprovincialis* beds on mud and sandy mud habitats along the Romanian Black Sea coast

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Introduction

The *Mytilus galloprovincialis* beds in mud and sandy-mud habitats are one of the most characteristic benthic communities on the NW Black Sea shelf, their territory ranging from 20 m down to 70 m in depth. The typical deep mussel bed ranges between 30–50 m depth. The total surface occupied by the mussel community beyond the Romanian coast is about 7000 km^2, being the the second largest community after *Modiolula* (Băcescu et al., 1971). *Mytilus galloprovincialis* represents a mass mollusk species in the Black Sea both in shallow rocky bottoms and in deeper sedimentary bottoms. During the 1970s to 1990s, in a period of increasing eutrophication, this habitat suffered a series of changes mainly characterized by a decrease in the number and abundances of associated species. This study, based on the results of research performed in the last 5 years, provides more knowledge concerning the assessment of the ecological state and spatial distribution of mussel beds, and their evolutionary tendencies on the Romanian Black Sea shelf.

Methodology

During several cruises carried out on board the R/V "*Mare Nigrum*," in the period of 2009–2012, 83 quantitative bottom samples were collected over a bathymetric interval of 20–65 m using a van Veen-type grab (0.14 m^2). The samples were processed by washing through 1.0 and 0.5 mm sieves. The biomass of bivalves was weighed on board as fresh (wet) visceral tissues after removing the shell.

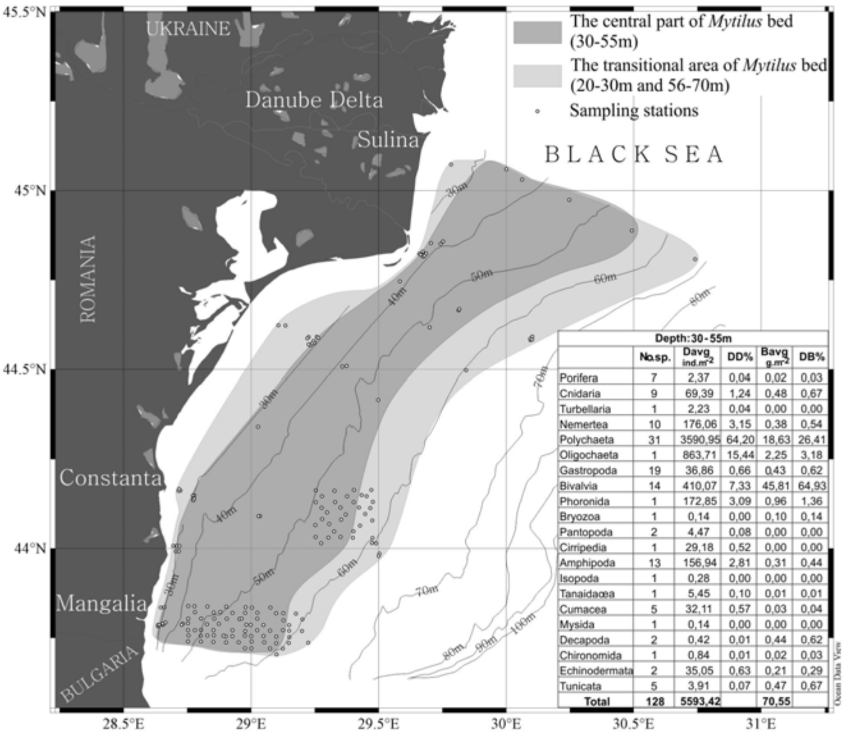
All living organisms retained by sieves were sorted and counted; the structure of the macro-benthic community was analyzed in terms of species composition, density, dominance, frequency, diversity, and biomass. Diversity was calculated by the diversity index (*H'*) on a log 2 base. The AZTI Marine Biotic Index, AMBI (Borja et al., 2000), and the multivariate AMBI, M-AMBI (Muxika et al., 2007) were calculated using the freeware program available on www.azti.es.

Results

A total of 140 macrobenthic taxa was recorded, the annelid worms being the dominant group (80%) followed by mollusks. The mean abundance of the populations was 5,076 ind.m^{-2} and 85.4 g.m^{-2} as biomass. Polychaeta had the highest richness value (35 species) and density (D_{avg}-3,200 ind.m^{-2}). The maximum biodiversity (128 species) occurred in the central part of the mussel beds (Fig. 1). According to the ecological indices, the characteristic species throughout the mussel community are: *Heteromastus filiformis* (F%-82), *Nephtys hombergii* (F%-81), and *Prionospio multibranchiata* (F%-52), *Phoronis euxinicola* (F%-56), and oligochaetes (F%-82).

The analysis of species distribution within the geographic sectors of the Romanian shelf underlined the differences between the northern sector (under direct influence of the Danube) and the southern one. In the northern area, *Dipolydora quadrilobata* with maximum densities of 15,000 ind.m^{-2} at 36 m depth on the Sulina transect, and *Melinna palmata* with maximum densities of 8,300 ind.m^{-2} at 27 m depth on the Sf. Gheorghe transect are the species forming a new association. *D. quadrilobata*, recently introduced into the Black Sea (in the 2000s), registered the greatest development, living on various types of sedimentary substrata (Begun et al., 2010). In the southern part, the polychaete worm *Aricidea claudiae* (max. 2,700 ind.m^{-2}) is the characteristic species for the transition interval between the littoral habitats and the typical *Mytilus* one. The constant bivalvia species within the mussel beds are *Abra alba* (F%-57) and *A. prismatica* (F%-55). *M. galloprovincialis* as a weight dominant species has a patch distribution with average abundance of 56 ind.m^{-2} and 14 g.m^{-2} w.wt. In the northern part (Sulina to Cape Midia), the mussel is the third species in weight dominance after *Mya arenaria* (31 g.m^{-2} w.wt.) and *Melinna palmata* (15 g.m^{-2}), the latter forming a distinct association within the mussel community. Analysis of the *Mytilus* community at bathymetric intervals reveals the importance of this coenotic unity as a biodiversity reservoir.

The spatial distribution of *Mytilus* presents 2 transition zones (20–30 m and 56–70 m), one situated at the boundary with the littoral communities and the other with the deep ones, and the typical mussel community is located (30–55 m) in between (Fig. 1).



Depth:30-55m					
	No.sp.	Davg ind.m^{-2}	DD%	Bavg g.m^{-2}	DB%
Porifera	7	2,37	0,04	0,02	0,03
Cnidaria	9	69,39	1,24	0,48	0,67
Turbellaria	1	2,23	0,04	0,00	0,00
Nemertea	10	176,06	3,15	0,38	0,54
Polychaeta	31	3590,95	64,20	18,63	26,41
Oligochaeta	1	863,71	15,44	2,25	3,18
Gastropoda	19	36,86	0,66	0,43	0,62
Bivalvia	14	410,07	7,33	45,81	64,93
Phoronida	1	172,85	3,09	0,96	1,36
Bryozoa	1	0,14	0,00	0,10	0,14
Pantopoda	2	4,47	0,08	0,00	0,00
Cirripedia	1	29,18	0,52	0,00	0,00
Amphipoda	13	156,94	2,81	0,31	0,44
Isopoda	1	0,28	0,00	0,00	0,00
Tanaidacea	1	5,45	0,10	0,01	0,01
Cumacea	5	32,11	0,57	0,03	0,04
Mysida	1	0,14	0,00	0,00	0,00
Decapoda	2	0,42	0,01	0,44	0,62
Chironomida	1	0,84	0,01	0,02	0,03
Echinodermata	2	35,05	0,63	0,21	0,29
Tunicata	5	3,91	0,07	0,47	0,67
Total	**128**	**5593,42**		**70,55**	

Figure 1. Distribution of *Mytilus galloprovincialis* beds on mud and sandy-mud habitats along the Romanian Black Sea shelf.

Thus, within 20–30 m (77 species), the annelids dominate in density (*Melinna palmata*, oligochaeta, *H. filiformis*), while *Mya arenaria*, does in biomass, followed by *M. palmata* and *N. hombergii*. The strip between 56–70 m (52 species) marks the transition toward the *Modiolula phaseolina* community, resulting in a qualitative and quantitative impoverishing of the macrobenthic populations. Here, the leading species *M. phaseolina* dominates numerically and by weight followed by oligochaetes and *H. filiformis* (by density), and *Mytilus* and *Terebellides stroemi* (by biomass). In the central part of the *Mytilus* beds, between 30–55 m in depth, *D. quadrilobata* is numerically dominant while the oligochaetes' contribution has decreased.

Assessing benthic quality status of marine and transitional water habitats requires setting up both (1) indices assessing the relative quality of the considered habitat, and (2) reference conditions for which such indices can be computed and used to infer the absolute ecological status of the considered habitat.

The period 1950–1970 will provide a reference value for good ecological status because it is characterized by a lack of major impacts at the so-called "ecological equilibrium period" (Băcescu et al., 1971). In that period, detailed studies on the benthic biocoenosis in the NW Black Sea were conducted.

The three indices for the macrozoobenthic communities provided a broad picture of the Ecological Quality Status of the ecosystem in the *Mytilus galloprovincialis* beds on mud and sandy-mud habitats. Diversity indices such as the Shannon-Wiener index (H′) and the AMBI and M-AMBI are common tools for measuring such community changes in benthic ecology and are also widely used for the assessment of ecological quality status (Kröncke and Reiss, 2010). In the present study, H′ and the AMBI and M-AMBI revealed good environmental quality in the *Mytilus* beds. Still, the effect of pollution was found for a small number of situations. In the case of the Sf. Gheorghe and Portita area (30–45 m depth), the low number of species associated with Poor and Moderate EcoQs as resulting from H′ calculation and Bad and Poor EcoQ according to M-AMBI could be an indication of an ecological perturbation in this area.

Two ecological state classification systems are developed under the MSFD definition of Good Environmental State for *Mytilus galloprovincialis* beds on mud and sandy mud habitats based on the historical baseline. Using the above classification systems, the results for diversity and biotic indices indicate good status for this habitat; they do meet the MSFD requirements for achieving good environmental status with respect to the macrozoobenthos.

The present method of intercalibration used by the European Union does not seem to be suitable for comparing the results obtained for all the studied water bodies. Because some inconsistencies in the classification have been detected, the metrics require further validation for a better understanding of the community response to different natural and/or anthropogenic pressures.

Conclusions

In general, the ecological state of macrozoobenthic populations has degraded in the NW Black Sea sector since 1980. Nevertheless, at the present time, the human pressures on the ecosystem have apparently not exceeded the capacity of resilience of the macrobenthic community systems, and the investigated area has achieved a good environmental status in proportion of 66%, the remaining 34% being below the level of good ecological state during the study period.

Despite all the changes recorded throughout the last decades within the community of deep mussels populations, the leading species *Mytilus galloprovincialis* populations remain the most vigorous, well adapted to the environmental pressures that have occurred, with a high range of resilience and having revealed adaptive trends toward neoteny; today, mussel size (usually less than 5 cm in length) is below the sizes of the past, when the valves reached 7–8 cm in length and were heavily loaded with calcareous concretions produced by *Melobesia* or *Lithotamnion*.

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Climate change and variability in the Black Sea–Mediterranean region

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Keywords: climate change, variability, Black Sea-Mediterranean region

The goal of this presentation is to study the features of climate change and interannual-decadal variability in the hydrometeorological fields over the Black Sea-Mediterranean region associated with global processes of the ocean-atmosphere system. The North Atlantic Oscillation (NAO) and the El-Niño-Southern Oscillation (ENSO) were considered as the main interannual teleconnected signals, while the Pacific Decadal Oscillation (PDO) was considered as a decadal one.

Introduction

Recent studies of natural climate variability and change over the Northern Hemisphere demonstrate that the main features are associated with low-frequency processes in the global ocean-atmosphere system (Enfield and Mestas-Nuñez, 1999). It is evidently now that the main interannual climate modes are NAO and ENSO. At the same time, decadal-multidecadal climatic signals responsible for the global and regional hydrometeorological anomalies are the Atlantic Multidecadal Oscillation (AMO) and the Pacific Decadal Oscillation (PDO) (Polonsky et al., 2013). Their strongest regional manifestations in the Northern Hemisphere with the increasing of gradients and variances of hydrometeorological parameters are in winter. A significant and separate influence of PDO and AMO on winter cyclonic activity in the Black Sea-Mediterranean region was shown by Voskresenskaya and Maslova (2011).

The scheme of North Atlantic multidecadal influence on the generation of European climate anomalies was described, for instance, by Polonsky et al. (2004). It illustrates that North Atlantic storm tracks shift to the northeast/southeast during negative/positive AMO phases. Such displacements in the atmosphere have typical hydrometeorological manifestations associated with cyclonic/anticyclonic conditions (Fraedrich et al., 1996; Holt, 1999). Unfortunately, such schemes for PDO have not been identified yet. As a result, it is clear that there are no comprehensive studies on joint manifestations of these climatic signals (AMO and PDO) in the variability of both global and regional cyclonic activity. One way to analyze the joint AMO and PDO influence on Northern Hemisphere temperature variations was presented in paper by D'Aleo and Easterbrook (2010), but it was not widely used due to many critical comments. That is why the aim of the present paper is to study and identify the patterns of joint AMO and PDO manifestations during winter cyclone activity on the global (Northern Hemisphere) and regional (Mediterranean and Black Sea) scales and associated changes in hydrometeorological fields.

Data and methodology

Daily and monthly NCEP-NCAR global reanalysis datasets from 1948–2014 in 1.75° x 1.75° regular grid degree points and monthly global historical LDEO (Lamont Doherty Earth Observatory, Columbia University, USA) data sets from 1856–2012 in 1.5° x 1.5° regular grid degree points were used in the study to select the anomalies, including extreme events. Quality control of these data sets was done and presented earlier by Mikhailova et al. (2008).

The following hydrometeorological fields limited by Black Sea and Mediterranean region borders were analyzed:

- Air (AT) and sea surface temperature (SST)
- Sea-level pressure (SLP)
- Wind speed components (U & V)
- Components of heat balance (B) on the air-sea interaction level:
- Latent (H), sensible (LE) and radiative (R) fluxes.

- NAO, Southern Oscillation (SO), and PDO indices were analyzed, too.

Results

Typical and anomalous conditions including extremes in the hydrometeorological fields and heat balance components over the Black Sea-Mediterranean region were considered to analyze linear and parabolic trends and to study the interannual variability associated with NAO, ENSO, and decadal variability associated with PDO. The following results are presented.

Linear trends are practically insignificant or quite small during the period 1948–2014 for all analyzed fields over the Black Sea-Mediterranean region. At the same time, parabolic trends are mostly significant and demonstrate that a periodicity of 20–30 years characterized the study fields in the region of interest. The examples for some points in the Eastern and Western Mediterranean, and in the Black Sea demonstrate this fact in Fig. 1. At the same time, the interannual and decadal scales of typical variability are clearly visible there.

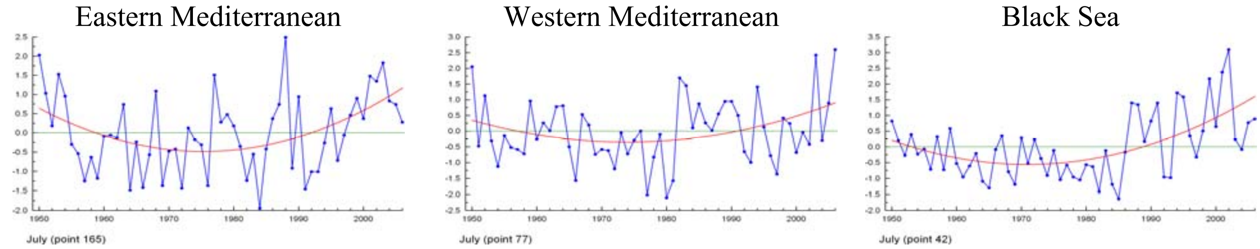


Figure 1. Monthly air temperature variations in July and parabolic trends in the Eastern and Western Mediterranean, and in the Black Sea, 1948–2006.

The interannual oscillations, NAO and ENSO, are responsible for a major part of the variance of all analyzed fields. It was shown that up to 50% of AT, SST, SLP, wind speed anomalies, and cyclonic activity is associated with joint NAO and ENSO influence. This analysis was done using the results of previous ENSO classification in the paper by Voskresenskaya and Mikhailova (2010). Three ENSO-type manifestations were considered in the NAO patterns. composite method, it was found that the first ENSO type is accompanied by a strong positive NAO phase; the second one, by a very weak anomaly over the North Atlantic field of SLP; while the third type is characterized by a strong negative NAO phase. Fig. 2a, b, and c confirm the explained result. Correlation coefficients between the ENSO index and the Black Sea region SLP anomalies reach 0.7–0.9 with a 3–7 month lag during each type of ENSO. The coincidence of their high phases is accompanied by more frequent climate-weather anomalies against the background of more intense air-sea interaction.

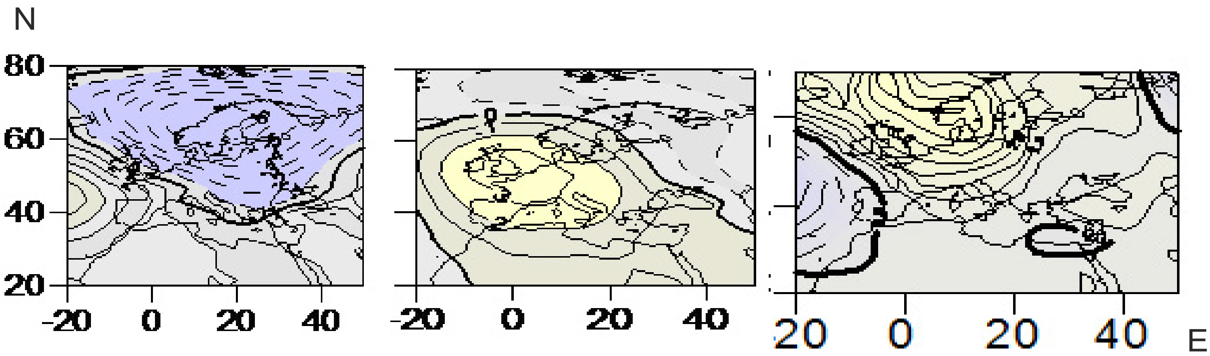


Figure 2. Composite maps of sea level pressure in the North Atlantic-European region (20º–80ºN; 20ºW–45ºE) corresponded to the 1st, 2nd, and 3rd ENSO types from 1856–2012.

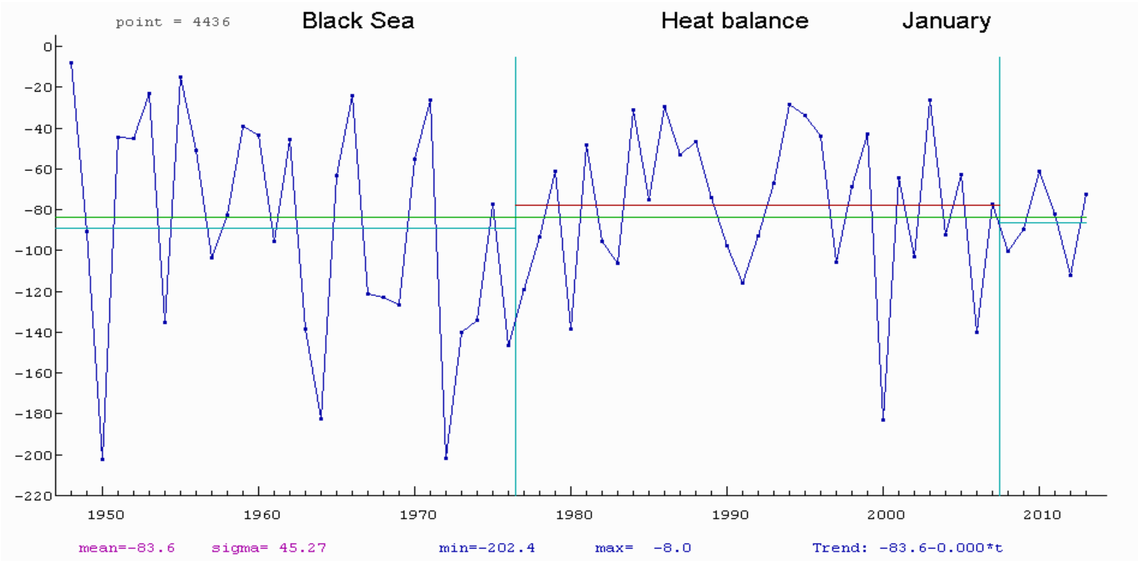
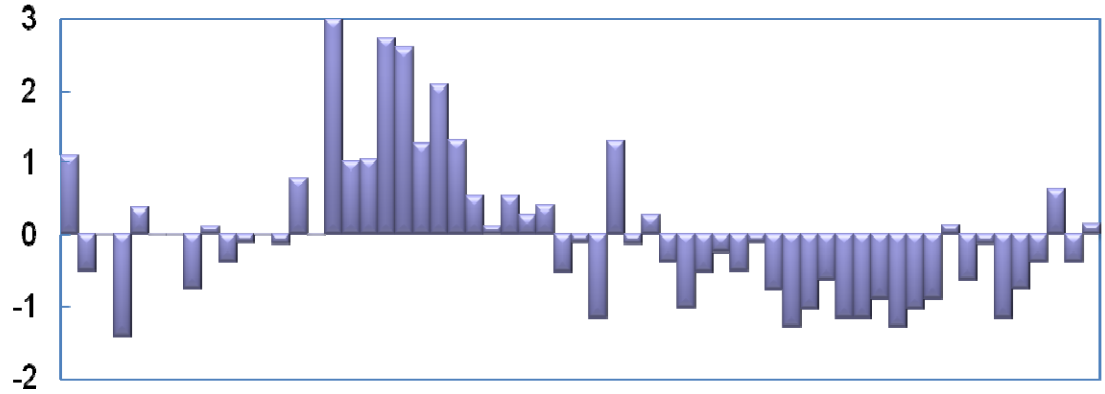
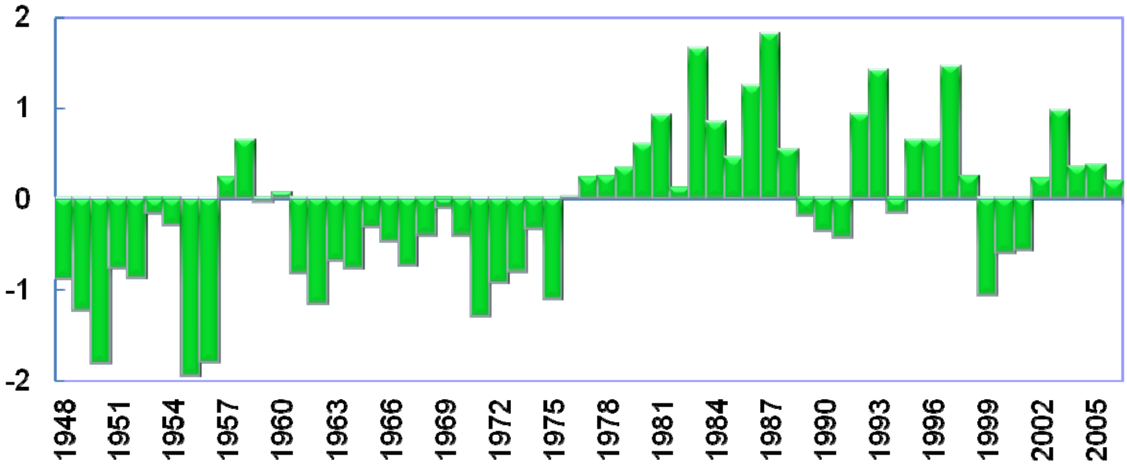


Figure 3. Graphs of heat balance change between negative PDO phases (1947–1976 and 2008–2014) and the positive PDO phase (1977–2008).

This situation is favored for more intense cyclogenesis and leads to doubling of cyclone frequency in the Black Sea region in winter-spring during negative PDO phases. The change of cyclone regime associated with the PDO phase change in 1976–1977 is illustrated by Fig. 4.



A



B

Figure 4. Normalized anomalies of cyclone frequency (a) and PDO index 1948–2008 (b).

Next, it was shown that the coincidence of NAO, ENSO, and PDO mature phases often leads to extreme events in the Black Sea region.

The detailed characteristics of climate change and variability of AT, SST, SLP, U, V, B, H, LE, R, and cyclonic activity over the Black Sea-Mediterranean region will be discussed in the presentation.

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Extreme precipitation across the Crimean Peninsula

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Keywords: precipitation, concentration index, precipitation inequality, indices of extreme precipitation

Introduction

The Crimean Peninsula possesses quite a small territory with diverse climate zones: steppe, mountain, and the climate of the southern coast of Crimea. Each type of climate zone is characterized by its own characteristics: precipitation patterns, temperature, and other meteorological parameters. One of the most important parameters is precipitation due to its extreme importance for sustainable development of agriculture and availability of fresh water. Extreme precipitation can lead to significant social and economic losses. At the same time, the Crimean Peninsula is a world famous recreation and tourism zone.

The aim of the present paper is to study the characteristics of extreme precipitation within the Crimean Peninsula on the basis of standard hydrometeorological observations in the period of 1951–2009. Data from daily precipitation observed at 18 meteorological stations in Crimea were used.

Methodology

In this paper we used the following two methods. The first is the concentration index (Martin-Vide, 2004). It permits assessment of the contribution of intense precipitation to the total amount (precipitation inequality). The second method is that of extreme precipitation indices (Peterson, 2001). The detailed description of the methodology is presented in Vyshkvarkova and Voskresenskaya (2014). At the same time, the methods of mathematical statistics, composite and regression analysis, were applied, too.

Results

Precipitation inequality. The concentration index (CI) was calculated for each season and whole year. Average values of CI in Crimea revealed the space distribution shown in Fig. 1. Minimum values of precipitation inequality are typical for the southwestern part, mainly centered in the area of Sevastopol and on the territory of the Kerch Peninsula. Maximum CI values are typical for the mountainous region of the peninsula and the northeastern part of Crimea.

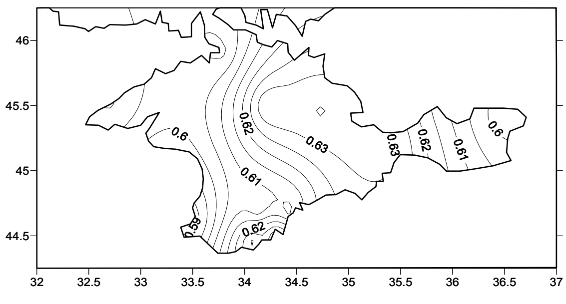

Fig. 1. Spatial distribution of average CI values.

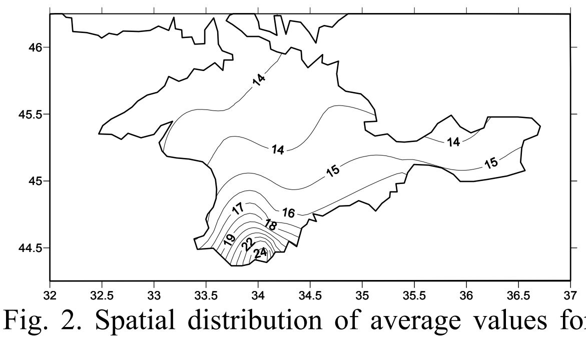

Fig. 2. Spatial distribution of average values for extreme precipitation level (95th percentile).

The winter season is characterized by the highest CI gradient. Throughout Crimean territory, CI values are less than 0.6 except for the Crimean mountains and southeastern climatic region. In spring, their values are higher than the average ones for the territory of Crimea. This pattern is typical for the central part of the peninsula and the south coast. The summer season is characterized by the highest values of CI. Its average value is about 0.63. Autumn is also characterized by high values of precipitation inequality, except the areas close to Sevastopol and Kerch.

Extreme precipitation. The precipitation values exceeding the 95th percentile (index R95) were considered to be characteristic of extreme precipitation. The spatial distribution for the whole year and all seasons except summer shows that the R95 index increases from the north to the south, with a peak in the mountain area (Fig. 2). In summer, extreme precipitation has a uniform distribution across the peninsula, its average values being about 24.5 mm/day.

Conclusions

As a result of analyses of precipitation inequality and level of extreme precipitation across the Crimean Peninsula during the period of 1951–2009, different precipitation climate types and precipitation regimes were found. On the annual, winter, spring, and autumn scales, CI values and the R95 index have similar distributions, with a maximum in the Crimean mountain region. The summer season is characterized by a uniform distribution of precipitation inequality and extreme precipitation across the study region.

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The Girkanian epoch in the Pleistocene history of the Caspian Sea

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Keywords: Northern Caspian Sea, late Quaternary, boreholes, marine sediments, structure

Introduction

G. Goretskiy (1957) and G. Popov (1957) established the Girkanian deposits in the northwestern Pre-Caspian lowland and the East Manych on the basis of more than 200 boreholes. Popov (1967) drew the conclusion that a large Girkanian transgression of the Caspian Sea occurred, for which traces are not found in other areas of the region. Characteristic features of its malacofauna are the prevalence of *Didacna cristata*, *D. subcatillus*, *D. hyrcana*, and the presence of a warm-water freshwater species, *Corbicula fluminalis*. V. Shkatova (1975), P. Fedorov (1978), and A. Svitoch and T. Yanina (1997) reacted with criticism to this position. In their opinion, Girkanian layers are merely the desalinated facies of Upper Khazarian deposits and not sediments from an independent transgression. L. Nevesskaya (2007) included the community of mollusks from Girkanian deposits within the Khvalynian fauna. The majority of researchers have accepted the point of view of Fedorov (1978) about the identification of upper Khazarian and Girkanian horizons in the stratigraphic scheme of the Caspian Pleistocene.

In recent years, in connection with petro-search work in the northern Caspian Sea area, new seismoacoustic data have been obtained, and a substantial number of engineering-geological boreholes were drilled. This now allows a revisiting of the problem involving the existence of the Girkanian epoch in the Pleistocene history of the Caspian Sea. The goal of this paper is to propose a solution to the controversial question about the Girkanian basin on the basis of the analyses conducted on the boreholes from the northern Caspian Sea.

Material and methods

The material basis for this paper emerges from the study of the sedimentary complexes of the upper part of Quaternary thickness on the Shirotnaya structure in the northern Caspian Sea. In this area, a large volume of seismoacoustic profiling and static sounding was done, and the drilling of many boreholes up to 100 m in depth was carried out during engineering-geological research. The cores were studied using lithological, biostratigraphic (mollusks), and geochronological methods. Radiocarbon dating was obtained by the scintillation method (Moscow and St. Petersburg State Universities, Russia) and an AMS method (Lawrence Livermore National Laboratory, USA).

Results

Based on our studies, the structure of the sedimentary sequence is represented in Figure 1. In the core sequence between two well-expressed horizons of regressive deposits—Chernoyarian (chr) and Atelian (at)—the thickness of the Caspian deposits reaches 28 m.

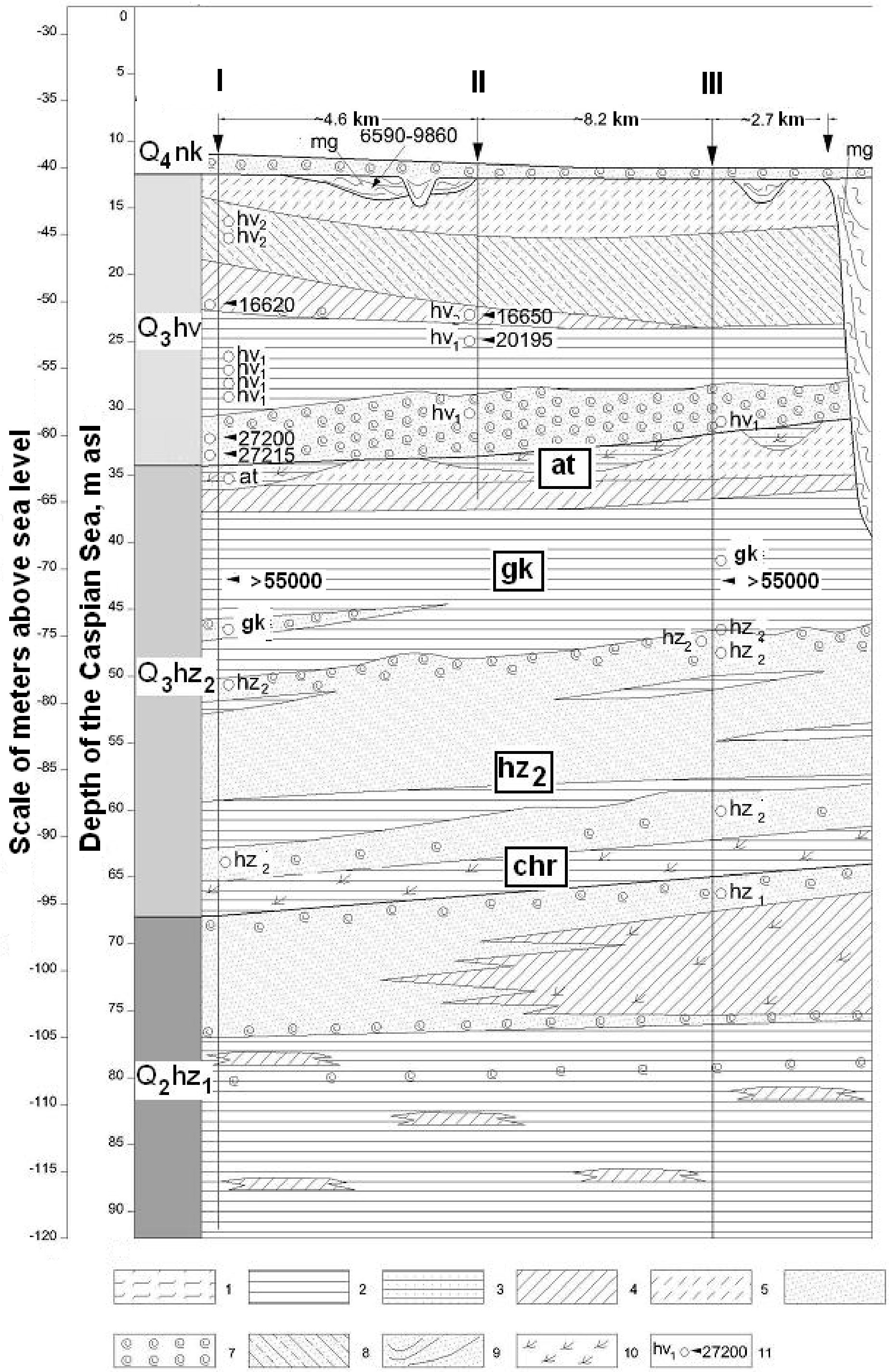

Fig. 1. Quaternary deposits opened by boreholes in the Shirotnaya area in the northern Caspian Sea.
1 – silt; 2 – clay; 3 – sandy clay; 4 – sandy loam; 5 – loam; 6 – sand; 7 – shells of mollusks; 8 – mix of sand and loam; 9 – hollows; 10 – vegetable remains; 11 – mollusks determination and ^{14}C dating. Geological age: chr – Chernoyarian; hz1 – Lower Khazarian; hz2 – Upper Khazarian; gk – Girkanian; at – Atelian; hv1 – Lower Khvalynian; hv2 – Upper Khvalynian; mg – Mangyshlakian; nk – New Caspian.

The Chernoyarian horizon is represented by sandy-clay sediments with the inclusion of vegetal remains and with signs of transformation to a subaerial environment. Above it, there lies packed sand with thicknesses up to 2 m. The sand includes *Didacna surachanica*, *D. nalivkini*, *D.* cf. *subcatillus*, *D. ovatocrassa*, and *D. surachanica*—the index species for Late Khazarian fauna. Above this, the sand is replaced by sandy clay up to 4 m in thickness, which then turns into a 10-m thickness of fine-grained sand with pro-layers of clay. These sediments contain rare *Didacna* with a similar species composition, and *Dreissena*. At the top of this thickness, there is a sandy-shell layer (about 1 m) that is partly cemented by carbonate. It includes *D. surachanica*, *D. nalivkini*, and *D. cristata*. To the west of this area, and within this layer, there are numerous *Corbicula fluminalis* and *Didacna nalivkini* in the joint bedding. The top part of the section is represented by quite uniform clay with thicknesses of more than 10 m. It contains sandy-shell layers and lenses. Among the shells, *Dreissena rostriformis distincta* prevail, *Dr. caspia* and *Didacna umbonata* are rare. In the top part, among the species of *Didacna*, *D. subcatillus* prevails, *D. subcatillus*, *D. cristata*, and *D.* cf. *parallella* are rare. The faunistic composition is characteristic of the Girkanian horizon and was allocated by Popov (1967). The upper regressive horizon (Atelian) is represented by a mix of the sandy and clayey material containing fragments of the freshwater mollusks *Unio* and *Limnea*, vegetal remains, and pro-layers of black peat material testifying to a continental genesis.

It is possible to conclude that there were two regressions during the paleogeographical development of the northern Caspian Sea at the beginning of the late Pleistocene. Accumulation of sediments in the basin of the Upper Khazarian complex happened at an initial stage of transgression, with shallow (basal layer) and moderately deep-water (sandy clays lying above) conditions. According to the malacofauna, the basin was warm-water with rather high salinity for the northern Caspian Sea. Change in the clay sediments to sands indicates a fall in the level of the Late Khazarian basin. The presence in the Upper Khazarian deposits of the thermophilous species *Corbicula fluminalis* is evidence of the development of the basin under warm interglacial conditions.

Accumulation of a blocking layer of moderately deep-water clays is connected to conditions within the transgressive basin and a maximum level for the considered period. It existed for a very long time judging by the thickness of the deposit. We consider it to be the Girkanian basin. Its faunistic configuration is defined by joint finding of the "Khvalynian-like" fauna—*D. subcatillus*, *D. cristata*, and *D. parallella*—and rare representatives of Late Khazarian fauna. Judging from the structure of the deposits, the Girkanian basin surpassed the Late Khazarian one in size. Dating by AMS radiocarbon method showed an age of >55 thousand years (the estimated geological age is beyond the range of radiocarbon).

Judging by the structure of Pleistocene deposits within the Manych, the Girkanian transgression formed deep gulf at the mouth of the Manych valley; the Karangatian ingression into the Manych valley took place from the Pontic basin at the same time. The overlapping of the Karangatian deposits by Girkanian sediments testifies to a draining of Girkanian waters into the Pontic basin after a fall in the level of the Karangatian basin.

Conclusions

The analysis of materials recovered by drilling in the northern Caspian Sea confirms Popov's conclusion about the existence in Caspian Pleistocene history of a Girkanian transgressive basin that developed after the Late Khazarian transgression. The Late Khazarian sediment complex characterizes a shallow and moderately deep-water transgressive basin. The Girkanian deposits reflect a transgression of higher level. The presence of *Corbicula fluminalis* in the basin's deposits testifies to warm-water conditions in the northern Caspian Sea. Both transgressions developed during MIS 5. The maximum level of the Girkanian transgression and the draining of its waters via the Manych passage occurred during the transitional stage from the Mikulino interglacial to the Valdai cold epoch.

Acknowledgments

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Stratigraphy and paleogeography of the Caspian Neopleistcene

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Keywords: Caspian Sea, Neopleistocene, marine sediments, complex analyses, malacofauna, stratigraphy, paleogeography, correlation

Introduction

In its development, the Caspian region reflects global climatic changes, and glacial and interglacial rhythmics of the East European Plain and mountain territories. Therefore, it is the stratotypical region for drawing up uniform stratigraphic and paleogeographic schemes for the Northern Eurasian Pleistocene. That is why studying its regional stratigraphy and history of development has drawn the attention of scientists over more than two centuries. Andrusov, Kalitskiy, Nalivkin, Bogachev, Pravoslavlev, Golubyatnikov, Kovalevskiy, Zhukov, Fedorov, Vasiliev, Moskvitin, Goretskiy, Vekilov, Rychagov, Popov, Nevesskaya, Leontiev, Mamedov, Alieva, Badyukova, Chepalyga, Kroonenberg, Leroy, Lahidjani, and many others are among them. This paper presents a biostratigraphic scheme for the Caspian Neopleistocene (the middle and late Pleistocene of the International scheme) as well as a reconstruction of the development of the successive basins of the Caspian Sea on the basis of generalized results from malacofaunistic analysis and materials deriving from the complex study of deposits from the Caspian region. The material was collected by the authors during many years of field and laboratory investigation of the basic sections of Pleistocene deposits and locations of Caspian malacofauna on all coasts of the Caspian Sea and within the Manych depression (Svitoch and Yanina, 1997; Yanina et al., 2005; Svitoch et al., 2010).

Stratigraphy

The biostratigraphy of the Caspian Neopleistocene is based on changes in the evolutionary patterns and ecological assemblages of the mollusk genus *Didacna* Eichwald. The authors have idenitified faunal groups of different taxonomic composition at different taxonomic levels. These studies have allowed a revision and supplementation of existing biostratigraphic schemes and suggestions for reference sites typifying all the stratigraphic units. Analysis of shells of *Didacna* revealed that they represent 74 species and subspecies. In the distribution of *Didacna*, the following faunas were singled out: Baku, Urunjik, Early Khazar, Late Khazar, Khvalynian, and New Caspian. Each of the faunas is characterized by (1) a particular ratio of major *Didacna* groups, and (2) a faunal group taxonomic composition, each with its own index-species and affiliation with a particular interval within the Caspian sediments, separated from under- and overlying sediments by traces of unconformity. In the Baku fauna, the *crassa* and *catillus* groups are abundant; the Urunjik fauna is characterized by the predominance of the *crassa* group; the Early Khazar fauna is dominated by the *trigonoides* group; and the Late Khazar fauna is dominated by the *crassa* group. The Khvalynian fauna is characterized by the *trigonoides* and *catillus* groups; in the New Caspian, we observe abundant *crassa* and *trigonoides Didacna*. It is evident that these faunas are both distinctive and linked with each other. In the paleogeography of the region, these faunas reflect major transgressive epochs.

Each fauna is represented by faunal complexes that are closely interrelated with each other, characteristic of sediment members of different age, and corresponding to separate stages in the transgression development. The complexes have a particular taxonomic composition of *Didacna* with characteristic species. Baku, Urunjik, and New Caspian faunas each have a single *Didacna* complex; Early Khazar fauna includes three complexes; Late Khazar and Khvalynian include two. Based on variability within one sediment member, most of the faunal complexes are divisible into subcomplexes, usually characteristic of separate stages of the transgression. Some areas of the Caspian coast are characterized by faunal complexes (subcomplexes) that differ from others and are defined as faunal associations. These discrete faunal assemblages at different taxonomic levels are used as a basis for establishing the biostratigraphy of the Neopleistocene of the Caspian Region (Fig. 1).

Stratigraphical scale		Biozone	Horizons	Groups of Didacna: crassa	trigonoides	catillus	Subzones (Faunas)	Index-species, characteristic species	Subhorizons	Interval zones (Faunal complexes)	Layers	Subcomplexes	Reference sections
Holocene		Didacna Eichwald	New Caspian				crassa-trigonoides (New Caspian)	***Cerastoderma glaucum*** *D. crassa* *D. baeri* *D. trigonoides*			modern	Mytilaster	Turali (Dagestan)
											middle New Caspian	Cerastoderma	
											lower New Caspian	D. crassa – D. trigonoides	
Pleistocene (Neopleistocene)	Upper		Khvalynian				trigonoides-catillus (Khvalynian)	***D. ebersini*** ***D. praetrigonoides*** *D. parallela* *D. protracta*	Upper Khvalynian	Late Khvalynian D. praetrigonoides			Enotaevka – Kopanovka - Tsagan-Aman (Lower Volga region)
									Lower Khvalynian	Early Khvalynian D. parallella-D. protracta			
			Upper Khazar				crassa (Late Khazar)	***D. surachanica*** *D. nalivkini*	upper Upper Khazar	late Late Khazar D. surachanica-D. nalivkini			Seroglazovka (Lower Volga region)
									lower Upper Khazar	early Late Khazar D. nalivkini			
	Middle		Lower Khazar				trigonoides (Early Khazar)	*D. subpyramidata* *D. paleotrigonoides* *D. shuraosenica*	upper Lower Khazar	late Early Khazar D. paleotrigonoides-D. nalivkini			Seroglazovka, Kopanovka (Lower Volga region)
									middle Lower Khazar	middle Early Khazar D. paleotrigonoides - D. subpyramidata – D. shuraosenica			
									lower Lower Khazar	early Early Khazar D. subpyramidata			
			Urundjik				crassa (Urunjik)	***D. celekenica*** *D. eulachia* *D. kovalevskii* *D. pravoslavlevi*			Late Urunjik	D. kovalevskii	Nephtyanaya balka (Kura depression)
											Early Urunjik	D. eulachia	
			Baku				crassa-catillus (Baku)	***D. parvula,*** ***D. catillus catillus*** *D. rudis* *D. carditoides*			Late Baku	D. rudis – D. carditoides	Gora Bakinskogo yarusa (Apsheron peninsula) Nephtyanaya balka (Kura depression)
											Early Baku	D. parvula- D. catillus	

Figure 1. Biostratigraphic scheme of the Caspian Neopleistocene.

The main taxonomic unit of regional biostratigraphic schemes is a biostratigraphic zone. The Neopleistocene of the Caspian belongs to the *Didacna* biozone. According to the development of faunas, the zone is subdivided into six subzones, which are fundamental for establishing the main regional stratigraphic unit, i.e., the horizon. The following horizons are recognized: Baku, Urunjik, Lower Khazar, Upper Khazar, Khvalynian, and New Caspian. Analysis of the distribution of major *Didacna* groups in the section shows that they can be easily used to identify with accuracy different sediment members in the Caspian due to *Didacna*'s evolutionary development. From the point of view of historical geology, these horizons correspond to transgressive epochs in Caspian history. Horizons, index, and characteristic (controlling) species are readily distinguishable.

Higher resolution stratigraphic units are interval zones. They are used to identify subhorizons and correspond to major transgressive stages, separated by regressions, within the transgressive epochs. The Lower Khazar horizon is subdivided into lower, middle, and upper subhorizons, characterized by corresponding faunal complexes. The Upper Khazar horizon is subdivided into lower and upper subhorizons. The Khvalynian horizon is subdivided into lower Khvalynian and upper Khvalynian subhorizons. Subhorizons are linked to the presence of characteristic species.

A minor stratigraphic unit—beds—was distinguished based on the mollusk subcomplexes. Beds record the initial and end parts of the transgressive stages. The smallest stratigraphic unit—members—was defined within some of the subhorizons and beds. They are characterized by malacological faunal assemblages showing low range oscillations of the basin reflected in variable facies. Mollusk associations, which we distinguished as faunal units at different taxonomic levels, reflect the spatial diversity of paleoecological environments in the basin and demonstrate the facies variety within the horizons, subhorizons, and beds. All recognized stratigraphic units are related to paleogeographic events at variable hierarchical levels (transgression, stage, phase) in the development of the basin. Type localities for the distinctive stratigraphic units were suggested. All are located in well stratified sections that are available for investigation and have been previously and thoroughly studied. Besides malacofauna, they contain other fossil remains (ostracodes, foraminifers, pollen, carpologic material etc.), the data on which, as well as on paleomagnetism, absolute chronology, lithology, and geomorphology, were taken into consideration during their selection.

Paleogeography

The Caspian Sea paleogeography is reconstructed on the basis of complex studies of the region's Neopleistocene deposits. Fig. 2 schematically presents the sequence of the Caspian basins and their characteristics in brief. The shading reflects the relative salinity of the basins: the higher the salinity, the more intense the gray color; arrows show the drain and migration direction of mollusks.

During most of the Neopleistocene, the Caspian Basin was enclosed. Overflow occurred from the Caspian basin to the Pontian Basin across the Manych Passage five times (during the Baku transgression, twice during the Early Khazar and Girkan transgressions, and twice in the Early Khvalynian transgression). During maximum transgressions, the surface area of the Caspian Sea increased as much as 250% compared to its current area, and water levels reached +50 m. The maximum level of the transgression was controlled by the height of the Manych threshold. Caspian Sea levels dropped as low as –150 m during maximum regressions, resulting in lake level variations of 200 m in the Neopleistocene. The salinity fluctuations were relatively small, no more than 6–7‰. During extensive transgressions (Baku, Early Khazar, Khvalynian), the basin became slightly fresher, but during small transgressions (Urundjik, Late Khazar, New Caspian), salinities were notably high. Within the Caspian Basin, transgressions occurred during cold climate conditions (the extensive transgressions) and in warm climate conditions (small transgressions). In their late stages, the climate of the cold transgressions became warmer and that of the warm transgression became colder.

Development of the transgressive rhythmics of the Caspian Sea is caused by many factors driven by global climate change. Glacial and interglacial events of the Russian Plain and mountain areas, the development of which was in turn also defined by global climate changes, had regional impact on the environmental evolution of the Caspian region. The cold extensive transgressions of the Caspian Sea developed synchronously in the cold (glacial) climatic epochs. The maximum height of the Caspian transgressions was limited by the elevation of the Manych threshold.

1	2	Caspian basins
Holocene	Holocene	**New Caspian** *Brackish-water (11-13 ‰), warm-water; level to -19 m; isolated basin*
		Mangyshlak regression (to -70 m)
Late Neopleistocene	Late Pleistocene	**Late Khvalynian** Brackish-water (11-12‰); moderate warm-water; level to 0 m; isolated basin
		Enotaevsk regression (to -110 m)
		Early Khvalynian *Brackish-water (10-12‰); moderate warm-water and cold-water; level to 50 m; an overflow through Manych to Pont*
		Atel regression (to -140 m)
		Gircanian Brackish-water (11-12‰); moderate warm-water; an overflow through Manych to Pont
		Regression
		Late Khazar Brackish-water (12-14‰), warm-water; level to -10 m; isolated basin
		Regression
Middle Neopleistocene	Middle Pleistocene	**Early Khazar (late)** Brackish-water (10-11‰), moderate warm-water and cold-water; ingression to Manych
		Regression
		Early Khazar (middle) Brackish-water (7-10‰), cold-water; level to 35-40 m; an overflow through Manych to Pont
		Regression
		Early Khazar (early) Brackish-water (7-10‰), cold-water; an overflow through Manych to Pont
		Regression (to -75 m)
		Urundjik Brackish-water (15-16‰), warm-water; level to -15 m; isolated basin
		Regression
Early Neopleistocene		**Late Baku** Brackish-water (13-14‰), moderate warm-water; level to 20 m; an overflow through Manych to Pont
		Early Baku Brackish-water (8-9‰), cold-water; isolated basin
		Tyurkanina regression -150 (up to -200) m; Matuyama-Bruhnes inversion

Figure 2. The Neopleistocene basins of the Caspian Sea (1-Russian scheme, 2-International scheme).

The cold transgressions of the Caspian Sea occurred during cryogygrotic (humid and cold) phases of the climatic cycle of the Russian Plain, bringing favorable conditions for glaciation. However, the moisture peak in the Caspian reached its maximum earlier than the glacial maximum. By the time of the glacial maximum on the Plain, a sea-level drop occurred simultaneously with the coldest conditions. Deglaciation and increased river discharge caused a new transgression. Sea-lake levels rose in short transgressive-regressive pulses. Warm regressions corresponded to the thermo-xerotic interglacial phase of the Plain.

Warm transgressions happened during cold intervals, and moistening phases within the interglacial epochs.

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Quaternary ecostratigraphy and paleogeographic reconstructions of the Caspian region based on benthic foraminifera

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Introduction

Stratigraphy and paleoenvironmental reconstructions of the Caspian Quaternary are based largely on changes in the evolutionary patterns and ecological characteristics of the mollusk *Didacna* Eichwald in coastal outcrops and drillholes (Yanina, 2005, 2013; Yanina and Svitoch, 2014 [this volume]).

In contrast, this paper is focused on ecostratigraphic and paleoenvironmental reconstructions of the Caspian Quaternary using benthic foraminifera as the main evaluation tool. The value of benthic foraminifera for these purposes is well known. They are ubiquitous in marine environments and have tremendous taxonomic diversity; therefore they have the potential for diverse biological responses to environmental changes. Their tests are readily preserved in sediments and are small and abundant compared to other larger hard-shelled taxa (such as mollusks). This makes them particularly easy to recover in statistically significant numbers (Yanko et al., 1999).

In our work, we follow the Russian divisions of the Quaternary System, which separates the Quaternary into the Eopleistocene (1.8–0.78 Ma), the Neopleistocene (0.78–0.01 Ma), and the Holocene (0.01–0.0 Ma) (Zhamoida, 2002). The boundary between the Eopleistocene and Neopleistocene coincides with the Matuyama-Brunhes reversal [MBR], which is readily traced in both the BS and CS regions at the bottom of the Lower Chaudian and Gurian horizons, respectively.

The first information on Caspian foraminifera was published by Ehrenberg (1873), who identified 23 species in the surface sediments of 132 stations located at water depths of 6–836 m. Most of the species were found in areas above 25 m water depth; with increasing depth, their number decreased to 1–2 species. At least two species (*Rotalia globulosa* Ehrenberg and *Textularia globulosa* Ehrenberg) were recognized as reworked from the Cretaceous. About one hundred years later, Bening (1937) described 13 benthic species. Klenova (1956) found three recent species and plenty of reworked Cretaceous foraminifera. None of the abovementioned studies provided data on the quantitative distribution of foraminifera except for Klenova (1956), who mentioned that 75% of the foraminiferal assemblages consist of *Rotalia beccarrii* (Linné). The most complete data set on recent foraminifera of the Caspian Sea was provided by Mayer (1980). She described 18 species, two of which (*Hemisphaerammina* sp. and *Saccammina* sp.) were given in open nomenclature, two others—*Miliamina fusca* (Brady) and *Trichohyalus aguajoi* (Bermudez)—are well known from the literature, and the rest were described by Mayer for the first time. There are some recent publications on modern foraminifera of the Caspian Sea (Ghane et al., 2014) and very few (Svitoch et al., 1992) on those from Quaternary sediments of the Caspian region.

Physical environment of the Caspian Sea

The Caspian Sea is a lake without outlets surrounded by five countries: Azerbaijan, Iran, Turkmenistan, Kazakhstan, and Russia. The length of its coastline is 5580 km. Its sea level is lower than msl and fluctuates depending on the water balance: it rises if the balance is positive and declines if it is negative.

The area of the Caspian Sea can be divided into three approximately equal parts: Northern, Middle, and Southern (Aladin and Plotnikov, 2004). The Northern Caspian is the shallowest part of the basin. It comprises 29% of the entire sea area, although its volume makes up less than 1%. The area of the Northern Caspian varies from 92,750 up to 126,596 km^2, and its average volume is about 900 km^3. The depth does not exceed 10 m (average = 6 m), about 20% of the area has depths less than 1 m (Zonn, 2000). The Middle Caspian comprises 36% of the entire area with a volume of about 35% of the sea. Its area varies from 133,560 to 151,626 km^2, and its average volume is about 26,400 km^3. The average depth is about 175 m, and the greatest is 790 m (Zonn, 2000). The Southern Caspian has the largest volume, which comes to about 64% of the total volume, and its area amounts to 35% of the total area of the sea. Its area ranges between 144,690 and 151,018 km^2, and the average volume is 48,300 km^3. It is the deepest part of the basin, with maximum depth reaching 1025 m. The average depth is 300 m (Zonn, 2000).

There is one more distinguished part of the basin: a shallow (<10 m) Kara-Bogaz-Gol gulf that connects with the Middle Caspian by a narrow strait. Its area comprises 3% of the total area of the sea and is about 15,000 km^2. Being lower than the level of the sea by approximately 3–4 m, the gulf constantly "drinks" the water from the Caspian Sea, and this water, in turn, quickly evaporates.

The water balance of the Caspian is mainly determined by river runoff and rainfall (its incoming part), evaporation and water outflow into Kara-Bogaz-Gol (its outgoing part). The ground water runoff into the Caspian Sea is insignificant and therefore is frequently disregarded as an incoming component of the water balance. The most important part of the incoming water balance is the Volga runoff that makes up almost 80% of the total riverine inflow.

The major abiotic parameter of the Caspian Sea is salinity (avg 12.85 psu). Therefore, the basin is considered to be a brackish one. The lowest salinity is observed in the Northern Caspian (avg 5–10 psu) and even less in certain areas adjacent to the deltas of the rivers Volga, Ural, and Terek (2–4 psu). The salinity of the Middle Caspian is 12.7 psu. Because the eastern coast of the Middle Caspian has no river runoff, the amount of rainfall is very low, and the evaporation is high, water salinity in calm weather of the surface coastal waters can reach 13.0–13.2 psu. The salinity of the Southern Caspian is 13 psu. This salinity is lower in areas adjacent to the deltas of the rivers Kura and Sefidrud, and also in the mouth of the river Atrek. The highest salinity is observed in the Kara-Bogaz-Gol gulf. This gulf is a huge evaporator of the Caspian, and its water is brine: 300–350 psu and even higher. Based upon salinity, the Caspian waters can be subdivided into an oligo-mesohaline area in the Northern Caspian, a meso-polyhaline area in the Middle and Southern Caspian, and a hyperhaline area in the Kara-Bogaz-Gol gulf. The average salinity of the Caspian Sea is lower than that of the ocean by approximately a factor of three. However, the salinity of Caspian water is not the only aspect that differentiates it from waters of the World Ocean; it differs also in its salt composition (Aladin and Plotnikov, 2004).

Material and methods

More than 300 samples from the sea and coastal outcrops were collected and studied in a multidisciplinary effort (Yanko 1989; Svitoch et al., 1992). A map of sampled locations is provided in Yanko (1989, 1990).

Live (Rose Bengal stained) and fossil foraminifera were investigated separately as described in Yanko and Troitskaya (1987), Yanko (1989), and Yanko-Hombach (2007). Samples were soaked and washed in distilled water through a 63 µm mesh sieve. Dried samples were split with a microsplitter to avoid sample bias; whenever possible, about 300 fossil foraminifera were picked by hand (flotation in CCl_4 was sometimes used) and counted for population statistics. Due to low number of tests, particularly in coastal outcrops, foraminiferal abundance per station was calculated in dry samples of 100 g weight.

All species were morphologically examined, taxonomically identified, and imaged using SEM. In our taxonomic work, we followed the suprageneric classification of the *Basics of Paleontology* (Orlov, 1959), in combination with the generic classification of Loeblich and Tappan (1988). All identified taxa were systemized as belonging to Protozoa (Class Sarcodina, Subclass Foraminifera). The collection of the Caspian foraminifera is stored in the Paleontological Museum, Odessa National University, Ukraine.

For population statistics, foraminifera are divided into dominant (<50% of a given population) and accessory species. Species that occur at ≥50% of all studied locations are considered to be widely distributed, 49–10% are frequent, 9–1% are rare, and <1% are trace. All Caspian species fall into the category of brackish fauna. Within this category, they can be divided into oligohaline (>7 psu), mesohaline (7–12 psu), polyhaline (12–14 psu), and euryhaline (>7–14 psu).

Our ecostratigraphic technique (Yanko-Hombach, 2007) is largely based on the alternation of foraminiferal assemblages and their ecological preferences in geological sections, supported by data on mollusks and occasionally C-14 assays. To delineate the main features of each assemblage and their abiotic characteristics, they are studied in different ecological settings of the Caspian Sea (Yanko, 1989, 1990).

Results and discussion

Twenty five species and subspecies of benthic foraminifera are identified in the Quaternary sediments of the Caspian Sea (Table 1).

Table 1. Quaternary foraminifera of the Caspian Sea (+ agglutinated species, * fossil only).

No	***Species***
1.	*Ammonia caspica* Stschedrina, 1975
2.	*Ammonia novoeuxinica* Yanko, 1979
3.	*Ammoscalaria* sp., in Yanko, 1989 +
4.	*Ammoscalaria verae* Mayer, 1968 +
5.	*Aubignyna eg gr. mariei* Margarel, 1970 *
6.	*Birsteiniolla macrostoma* Mayer, 1968 +
7.	*Cornuspira minuscula* (Mayer), 1968
8.	*Elphidium caspicum caspicum* Yanko, 1989
9.	*Elphidium caspicum karadenizum* Yanko, 1989 *
10.	*Elphidium eg gr. gunteri* Cole, 1931
11.	*Elphidium shochinae* Mayer, 1968
12.	*Florilus trochospiralis* Mayer, 1968
13.	*Haplophragmoides tenuicutis* (Mayer), 1972 +
14.	*Haynesina eg gr. germanica* Ehrenberg 1840 *
15.	*Hemisphaerammina* sp. +
16.	*Jadammina polystoma caspica* Mayer, 1968
17.	*Mayerella brotzkajae* (Mayer), 1968
18.	*Mayerella ex gr. brotzkajae* (Mayer), 1968
19.	*Miliammina fusca* (Brady) +
20.	*Miliolinella risilla* Mayer, 1972
21.	*Ovammina leptoderma* Mayer +
22.	*Porosononion martkobi tschaudicus* Yanko, 1989 *
23.	*Psammmosphaera* sp., in Yanko, 1989 +*
24.	*Saccammin*a sp. +
25.	*Spiroplectinata perexilis* (Mayer), 1968 *
26.	*Trichochyalus aguajoi* (Bermudez), 1935

Geographically, foraminifera form 17 assemblages (Table 2). The species distribution is 5 times poorer compared to the Black Sea (Yanko-Hombach, 2007) and 20 times poorer compared to the Mediterranean Sea (Cimerman and Langer, 1991).

Table 1. Live foraminiferal assemblages of the Caspian Sea (from Yanko-Hombach, 2007, Table 2).

Part of the Caspian Sea	Connection with open basin	River discharge	Area	Depth (m)	Salinity (psu)	Number of stations	Number of species	Dominant species, max %	Accessories species	Assemblage index
		Very strong	Volga River delta	>3	0.1-7.5 (*avg* 2.3)	10	3	*Ammonia caspica,* 96	*Ma. brotzkajae* *M. fusca*	Vo
Northern	Free	Strong	Northeastern inner shelf	>17	7-9	11	9	*A. caspica,* 73 *Am. verae,* 17	*Ma. brotzkajae*	NC-1
		Weak	Northwestern inner shelf	>22	9-12	11	9	*A. caspica*, 66 *Am. verae,* 19	*E. caspicum caspicum* *M. fusca*	NC-2
		Strong	Western inner shelf	>35	11-12.5	11	11	*Am. verae*, 31 *A. caspica*, 23	*C. minuscula*	CC-1
		Weak	Western outer shelf	36-70	12.4-12.9	11	3	*A. caspica,* 88	*M . fusca* *C. minuscula*	CC-2
	Free	Absent	Eastern inner shelf	>35	12.7-13	11	14	*A. caspica,* 50	*E. caspicum caspicum*	CC-3
Central		Absent	Eastern outer shelf	36-70	12.7-13	11	3	*A. caspica,* 89	*M. fusca* *C. minuscula*	CC=4
		Absent	Krasnovodsky Bay	>5	14-15	11	17	*Am. verae,* 55	*S. perexilis*	Kr
	Restricted in 1968	Absent	Kara-Bogaz –Gol Bay	>2	13-14	11	13	*A. caspica,* 54 *B. macrostoma,* 28	*T. aguajoi*	KBG-1
	Absent in 1981	Absent	Kara-Bogaz –Gol Bay	>2	60-65	11	4	*T. aguajoi,* 80	*B. macrostoma*	KBG-2
	Free in 1968	Absent	Kara-Bogaz –Gol Strait	>2	12.2-13.3	11	12	*A. caspica,* 43	*Am. verae*	KBG-s
		Very strong	Kura delta	>10	>3	6	3	*A. caspica,* 97	*M. brotzkajae*	Kd
		Absent	Western inner shelf	>35	12.2	11	18	*E. caspicum caspicum,* 20	*E. shohinae*	SC-1
		Absent	Western outer shelf	36-70	12.8	11	3	*A. caspica,* 91	*M . fusca*	SC-2
Southern	Free	Weak	Turkmensky Bay	>35	12.6-13.2	11	12	*A. caspica,* 70	*E. caspicum caspicum*	Tu
		Absent	Eastern inner shelf	>35	13	11	18	*A. caspica*, 66 *E. caspicum caspicum,* 22	*E. schohinae*	SC-3

Twenty species (mostly endemic) live in the Caspian Sea today to a maximum depth of 70 m while the remaining five species are fossil (Yanko 1989, 1990).

The Eopleistocene is represented by the Apsheronian horizon, which consists of denuded limestones with nine species of foraminifera (*E. ex gr. gunteri*, *H. ex gr. germanica*, *A. ex gr. mariei*, *A. novoeuxinica*, *E. capsicum karadenizum*, *P. martkobi tschaudicus*, *M. ex gr. brotzkae*, *F. trochospiralis*, and *T. aguaioi*). On average, the number of specimens is >100 (occasionally up to 400). About 70% of the species are fossil (Table 1). Some of them (*E. gunteri*, *H. germanica*, and *A. mariei*) are described from upper Pliocene deposits of the North Atlantic (Knudsen, 1988) and Western Europe (Brodniewicz, 1972; Feyling-Hanssen et al., 1971). Other species (*E. capsicum karadenizum* and *P. martkobi tschaudicus*) are known from Pontic sediments. There are three survival species (*A. caspica*, *A. novoeuxinica*, and *F. trochospiralis*) that play a dominant role in foraminiferal assemblages of the modern Northern Caspian Sea, enabling us to evaluate the salinity of the Apsheronian basin as having been around 7 psu.

The lower Neopleistocene is represented by the Bakinian horizon overlying with erosional unconformity the Asheronian horizon. The Bakinian horizon has been studied in the stratotype "Gora Bakinskogo Yarusa" [the Mountain of Bakinian stage] (Svitoch et al., 1992) and outcrops "Neftyanaya Balka" and "Uzun-Dere (Maloe Kharami)." The foraminiferal assemblage includes 13 species and is characterized by a decrease in Eopleistocene relics and an appearance of Neopleistocene species (*M. brotzkajae*, *C. minuscula*, and *M. fusca*). Based on lithological properties, the Bakinian horizon is subdivided into lower and upper parts based upon early and late Bakinian foraminiferal assemblages.

The early Bakinian assemblage contains ten species of foraminifera with rather high abundance (up to 1700 specimens). It includes two Eopleistocene relics (*Haynesina ex gr. germanica* and *Aubignyna ex gr. mariei*). A dominant role is played by *A. caspica* and *P. martkobi tschaudicus* (together 80%). An accessory group consists of frequent *A. novoeuxinica*, *F. trochospiralis*, rare *E. capsicum karadenizum*, *M. brotzkajae*, and trace *M. fusca.* There is no recent analogue to the early Bakinian assemblage. The closest one is the NC-2 recent assemblage that is distributed in the Northern Caspian Sea at water depths <22 m and salinity 9–12 psu (Table 2). The late Bakinian assemblage contains ten species with decreased abundance (<200 specimens). The dominant species is *A. novoeux*inica (96%), *E. capsicum karadenizum* is frequent. Other species are rare or trace. There are no recent analogues to this fossil assemblage. The closest one is the CC-3 recent assemblage that inhabits the central part of the Caspian Sea at water depths >35 m and salinity 12.7–13 psu (Table 2). Comparison of both assemblages enables us to conclude that during Bakinian time, salinity increased from 10 to 14 psu.

Based on mollusks (Yanina, 2005, 2012; Yanina and Svitoch, 2014 [this volume]), the Middle Neopleistocene includes the Urunzhikian and Gyurgyanian (= lower Khazarian) horizons. We did not have material from Urunzhikian outcrops, and therefore, no description of foraminifera from the Urunzhikian horizon is provided. The Gyurgyanian horizon was studied in the outcrops "Uzun-Dere," "Adzhikabul," "Atachay," "Siazanskaya Mul'da," and "Nikol'skoe" (Northern Caspian region), where the Gyurgyanian horizon is underlain by coarse terrigenous sediments, mainly gray sands and pebbles, accumulated during a regressional stage when sea level dropped to –75 m (Yanina, 2012). The thickness of the Gyurgyanian sediments varies from 1 m to 300 m (in depressions). Mollusks are similar to those from the recent Caspian Sea, while the role of Pliocene relics is insignificant (Fedorov, 1978). The same applies to foraminifera, which are represented by 5–7 species with average abundance around 60 (sometimes 200) specimens. The dominant species are *A. caspica* and *M. brotzkajae* (95–97%). An accessory group is represented by frequent *A. novoeuxinica*, *F. trochospiralis*, rare *P. martkobi tschaudicus*, *M. fusca*, and trace *E. capsicum karadenizum*. The Gyurgyanian assemblage is rather close to the NC-1 and NC-2 recent assemblages (Table 1), enabling us to estimate the salinity of the basin at around 10 psu, excluding the Northern Caspian where it did not exceed 7–8 psu.

The upper Neopleistocene is represented by the upper Khazarian (Fedorov, 1978) and Khvalynian horizons, which have been studied in the "Yenotaevka-I" and "Lenino" outcrops that contain almost similar foraminiferal assemblages at their bottom. Dominant species are A. *novoeuxinica* and *E. capsicum capsicum* (98%). Variations are present in an accessory group of species. In particular, the late Khazarian assemblage at "Yenotaevka-I" bears some traces of freshening (absence of *E. schochinae* and *A. exiguous contractus*). In general, the late Khazarian assemblage contains nine species of foraminifera (up to 100 specimens). It differs from all the other abovementioned assemblages by the disappearance of Apsheronian *P. martkobi tschaudicus* and *E. caspicum karadenizum*, and appearance of *E. caspicum caspicum* and *E. schochinae.* The late Khazarian foraminiferal assemblage bears some similarity with the recent SC-1 and CC-1 assemblages, enabling us to evaluate the salinity at around 12–13 psu.

The Khvalynian horizon was first described by Andrusov (Pravoslavlev, 1913) as sediments corresponding to the widest transgression in the Caspian. Their accumulation took place under numerous sea-level oscillations that left geomorphological evidence in the form of terraces and coastal bars at absolute elevations between –17 m and 48 m asl. Foraminifera were studied in a number of outcrops located within the lower Volgian stratoregion ("Yenotaevka," "Nikol'skoe," and "Lenino") and in some other regions (outcrops "Adgicabul," "Atachay," "Siazanskaya mulda," "Chernyiy Yar," "Raygorod," "Svetlyiy Yar," and "Nizhnee Zaymische"). Foraminiferal assemblages from all these outcrops form a rather similar Kvalynian assemblage that can be divided into two sub-assemblages (early and late Khvalynian) associated with lower and upper Khvalynian sub-horizons identified with mollusks.

The lower Khvalynian sub-horizon is represented by nearshore or shallow sands, sandy clays, and rarely clays and pebbles. Its characteristic feature is the presence of lenses of chocolate-fulvous clays with thickness about 30–40 m. Total thickness of the lower Khvalynian sediments on the platform is about 10 m, sometimes 20 m. It increases up to 100 m and more in the Western Turkmenian, Kurinian, and North Dagestanian tectonic depressions (Fedorov, 1978). The coastline of the early Khvalynian basin can be traced at 40–50 m asl (Popov, 1983). The foraminiferal assemblage is quite monotonous. It includes the lowest number of species among all other Quaternary assemblages: six with abundance <250 specimens. The dominant species are *A. novoeuxinica*, *M. brotzkajae*, and *F. trochospiralis*. A significant number of young generations and a high frequency of large tests indicate favorable environmental conditions for their survival. Morphologically (especially concerning the tests of *A. caspica* and *M. brotzkajae*) and quantitatively, the early Khvalynian foraminiferal assemblage is identical to the recent CK-1 assemblage indicating a strong refreshening (up to 7 psu) of the early Khvalynian basin.

The upper Khvalynian sub-horizon has a significantly narrower distribution compared to the lower Khvalynian, being restricted by isohypse 26–27 m asl (Fedorov, 1978). The foraminiferal assemblage includes dominant *A. caspica* (96%) and accessory *M. brotzkajae*, *E. caspicum caspicum*, *F. trochospiralis*, and *A. exiguous*, with an abundance of 20–30, sometimes 100 specimens. Species *A. exiguous* is widely distributed today from the Atlantic lagoons to the Caspian Sea and from Pliocene to recent. Its appearance in this foraminiferal assemblage may indicate some normalization of the salinity regime (change in the content of salts and an increase in the amount of carbonates, probably due to evaporation).

Comparison of both sub-assemblages enables us to conclude that the early Khvalynian basin was much bigger compared to the late Khvalynian one and had a much lower salinity (7–8 psu) compared to the late Khvalynian one (12–14 psu).

The youngest sediments in the Caspian region were first described by Andrusov (1900–1901) as belonging to the Caspian horizon. Bogachev (1903) called them New Caspian. Fedorov (1946) applied this term to Holocene sediments of the entire Caspian region. The Holocene foraminiferal assemblages have been studied in several cores recovered in the western Caspian Sea, where seven foraminiferal assemblages are identified (Yanko, 1989). Four of them contain elevated frequencies of meso- and polyhaline species, while three others reveal oligohaline species. The former are distributed in coarse sediments, even conglomerates, and correspond to regressive stages of the basin's development. We call them (after Fedorov, 1978) Mangyshlakian, Chelekenian, Derbenian, and Recent beds, with corresponding foraminiferal assemblages. Oligohaline species are present in fine sediments and form the lower, middle, and upper New Caspian foraminiferal assemblages that correspond to the transgressional stages of basin development. In all seven assemblages, a dominant role is played by the oligohaline *A. caspica*. However, in the New Caspian assemblage, this species is supplemented by the oligohaline *M. brotzkajae* (up to 20%), while in the Mangyshlakian, Chelekenian, Derbenian, and Recent assemblages it is supplemented by the mesohaline *E. capsicum caspicum* (up to 20%). Within the accessory group in the New Caspian assemblages, frequent species are the oligohaline *A. verae*, *M. fusca*, and *F. trochospiralis*, while in the Mangyshlakian, Chelekenian, Derbenian, and Recent assemblages, the polyhaline *T. aguaioi* is frequent. In general, the Mangyshlakian and Chelekenian assemblages are rather close to SC-1 (12.1–12.2 psu), while the New Caspian is close to NC-1 (7–9 psu).

In general, the Holocene assemblages differed from the Eopleistocene and Neopleistocene ones by: (1) high frequencies of agglutinated species (*S. perexilis*, *H. tenuicutis*, *O. leptoderma*, *B. macrostoma*, *Hemisphaerammina* sp., and *Saccamina* sp.), most of which are known from the modern Caspain Sea only; and (2) very high abundances of foraminifera (tens of thousands of specimens). The stratigraphic position of the Holocene is defined by the appearance of agglutinated *A. verae* and *J. polystoma dacica*, and the wide distribution of *E. schochinae*, the youngest descendant of the Pliocene species *E. gunteri*.

Thus, in the Holocene, the Caspian Sea developed through a rhythmic regime consisting of alternations in transgressive and regressive stages with corresponding salinity 7–9 psu and 12–13 psu, respectively. Our data are in a good agreement with results obtained from mollusks (Yanina, 2012).

Conclusions

1. Most foraminiferal species in the Caspian Sea are endemics. However, among them there are Atlantic, Mediterranean, and Black Sea elements.

2. The biodiversity of Caspian foraminifera is 5 times poorer compared to that in the Black Sea (Yanko-Hombach, 2007) and 20 times poorer compared to that in the Mediterranean Sea (Cimerman and Langer, 1991). This can be explained by the long isolation of the Caspian Sea from the World Ocean, its low salinity, and the specific content of salts in the basin.

3. The boundaries between major Quaternary units in the Caspian region are determined by the most substantive changes in taxonomic content and structure of foraminiferal assemblages, in particular, on the decrease (up to total disappearance) of Pliocene-Eeopleistocene relics upward within the sedimentary column. More detailed stratification is based on emigrational sequences of foraminiferal assemblages; in particular, regressive stages in basin development are characterized by increases in meso- and polyhaline foraminifera while transgressive stages are characterized by their decrease as well as increase in oligohaline and holeuryhaline species.

4. The boundary between the Eopleistpocene and early Neopleistocene in the Caspian region is determined by the first appearance of Neopleistocene species (*M. brotzkajae*, *C. minuscula*, and *M. fusca*) that occur together with numerous Eopleistocene relics (*A. ex gr. mariei* and *H. ex gr. germanica*). Their vertical distribution is limited by the lower Neopleistocene.

5. The boundary between the early and middle Neopleistocene is determined by the decrease in Eopleistocene relics in the geological sequences.

6. The boundary between the middle and upper Neopleistocene is determined by the total disappearance of Apsheronian *P. martkobi tschaudicus* and *E. caspicum karadenizum* and the appearance of *E. caspicum caspicum* and *E. schochinae.*

7. Only a unilateral exchange of faunas occurred when the Caspian and Pontic basins were connected. The Caspian always shared its foraminifera with the Pont, but not *vice versa*.

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Evaluating the influence of river discharge on marine benthic ecosystems using benthic foraminifera and lithology as the main tools

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Introduction

River discharge has a significant impact on marine environment through its effect on the salt balance of the thermohaline structure and convection circulation of the water masses. Being enriched in the various organic and inorganic compounds, river flow is actively involved in biological processes and sedimentation, affecting the equilibrium state of the benthic ecosystems. Spatial distribution of river flow in the marine environment depends on meteorological and hydrological conditions that are characterized by inter-annual variability and varying proximity to the source. Coastal areas located in the confluence of major rivers experience the strongest impact of freshwater discharge. The northwestern shelf of the Black Sea—where the second largest river in Europe, the Danube, discharges annually 190.7 km^3 and 51.7 million tonnes of liquid and solid waste, respectively (Bondar et al., 1991; Panin, 1996), is a good example of such areas. Tracing the spatial distribution of river water into the sea and assessing its impact on benthic ecosystems have important theoretical and practical significance, both for understanding the causes affecting their balance, and for the development of methods and approaches to maintain their stability. Therefore, the choice of a reliable group of organisms as indicators of river discharge into the sea has primary significance. Such organisms should be benthic, small in size, and abundant (for population statistics), have a short life cycle, and be well preserved after death.

Benthic foraminifera perfectly fit these requirements. They play a significant role in global biogeochemical cycles of inorganic and organic compounds, making them one of the most important animal groups on earth. They are ubiquitous in marine environments. Their tremendous taxonomic diversity gives them the potential for diverse biological responses to various pollutants, which in turn adds to their potential as an index species for monitoring pollution from diverse sources. Their tests are readily preserved and can record evidence of environmental stresses through time, thus providing historical baseline data even in the absence of background studies. They are small and abundant compared to other larger hard-shelled taxa (such as mollusks, which are often used for pollution monitoring), and this makes them particularly easy to recover in statistically significant numbers. They have very short reproductive cycles (six months to one year) and rapid growth making their community structure particularly responsive to environmental change. They often show species-specific responses to ecological conditions. They have biological defense mechanisms which protect them from unfavorable environmental factors, thus providing detectable biological evidence of the pollution effect. All these characteristics make them powerful tools for continuous *in situ*, biological monitoring of marine environments (Yanko et al., 1999).

This paper focuses on tracing the Danube River discharge into the Black Sea and its influence on bottom ecosystems using complex analysis of benthic foraminifera and lithological properties of the sediments as the main tool. The study was conducting recently within the framework of the international project BS-ERA.NET 076 "Water Pollution Prevention Options for Coastal Zones and Tourist Areas: Application to the Danube Delta Front Area," WAPCOAST (2010–2012).

Study area

The study area includes the southern (Romanian) part of the northwestern corner of the Black Sea located between the Danube delta and Cape Kaliakra (Fig. 1).

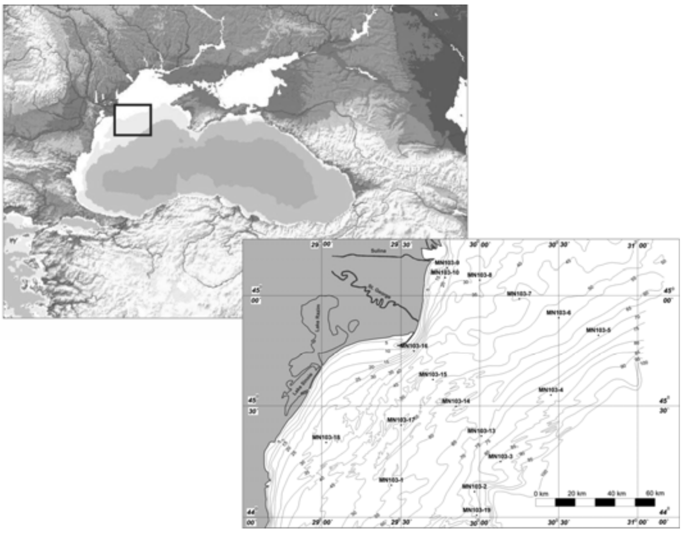

Figure 1. Study area and location of sampling stations.

The study area includes the seaside (water depth >5 m), submerged part of the delta (5–25 m), pro-delta located on the inner and partially outer shelf (25–50 m), and the outer shelf.

The seaside of the Danube Delta is located parallel to the shore, has an 8–10 km width, and is characterized by a strong mixture of marine and fresh water. The width of the seaside varies significantly depending on the amount of Danube solid runoff being closer to the shore or moving away from it. The distribution of sedimentary material here is under the strong influence of longshore currents that form a series of bars and spits in the wave-cut zone.

The seabed of the submerged part of the delta has a relatively steep slope. The relief is formed mainly by the deposition-removal processes of sediment runoff. Despite the fact that the Danube discharges annually into the Black Sea 25–35 million tons of solid material, the bulk of it is carried away by longshore currents to the south, being exposed to erosion south of the Sulina mouth. Therefore, the sedimentation rate here is low and does not exceed 5–10 cm/1000 years (Panin and Jipa, 2002).

The prodelta is characterized by deposition of sedimentary material. Due to the weak impact of wave processes and active accumulation of sediments, the delta grows fast. There is a zone of geochemical barrier at the boundary between river and sea water. In this zone, an intensive abiogenic flocculation develops leading to the formation of vast areas of pelites.

Material and methods

Seventeen stations have been sampled using the Romanian R/V "Mare Nigrum" during the period from 3 to 7 May 2012. Sampling was performed by 0.1 m^2 van Veen grab and multicorer (Mark II-400 with four tubes, each 60 cm long and 10 cm in diameter) that enabled the recovery of up to a 40 cm sediment column.

The hydrological parameters were obtained by Neil Brown Instruments Systems (CTD), equipped with 11 samplers and electronic sensors. They include water depth (D), dissolved oxygen (DO), saturation index of oxygen (SI), salinity (S), electrical conductivity (U), temperature (T°C), pH, and Eh (subsequently normalized to a standard pH = 7 and indicated as Eh'). Transparency (Tr) was measured using a Secchi disk. The content of PO_4 and SiO_2 is determined using the Molybdovanadate Method with Acid Persulfate Digestion (HASH equipment) on board.

The $CaCO_3$ content is determined by titration. Carbon (C), organic carbon (C_{org}), and nitrogen (N) in the sediments are determined by gas chromatography using a Carlo Erba NA 1500 with an accuracy of 0.01%, 0.02%, and 0.002%, respectively. The $^{15}N/^{14}N$ ratio was expressed as $\delta^{15}N$ and determined by the mass spectrometer Finnigan MAT 252, after processing the samples at 1100°C in a gas chromatograph at the Institute of Biogeochemistry and Marine Chemistry, University of Hamburg in Germany.

Grain-size distribution (sieve and elutriation) together with determination of Median Diameter (Md) and coefficient of sorting (So) as well as foraminiferal analysis performed for the uppermost 0–2 cm layer of sediments as described in Logvinenko and Sergeeva (1986) and Yanko and Troitskaya (1987), respectively, at the laboratory of Micropaleontology, Odessa I.I. Mechnikov National University, Ukraine (Yanko-Hombach et al., 2013).

According to their ecological preferences, foraminifera are divided into oligohaline (1–5 psu), strictoeuryhaline (11–26 psu), polyhaline (18–26 psu), holoeuryhaline (1–26 psu), shallow (0–30 m), relatively deep (31–70 m), and deep (71–220 m) species (Yanko-Hombach, 2007).

All measured parameters were treated statistically (cluster, correlation, factor analyses, and multidimensional scaling) using the Statistics-7 package in order to find out the main factor/s responsible for taxonomic and spatial distribution of foraminifera. Correlation in this study was considered strong and meaningful if $r \leq 0.52$ ($P < 0.05000$), at greater than the 95% confidence level. If $r = 0.5–0.4$ ($P < 0.0500$), we would consider such correlation to be a trend.

Results and Discussion

No planktonic species were discovered. Benthic foraminifera are represented by 15 species (14 calcareous and one agglutinated) from 3 orders, 7 families, and 14 genera. The orders Rotaliida, Lagenida, Ataxophragmiida were represented by 8, 5, and 1 species, respectively. Among the Rotaliida, the dominant species of the genus *Ammonia* were *A. tepida*, *A. compacta*, *A. Ammoniformis*; among the Lagenida, it was *Fissurina lucida*. The rest of the species belong to an accessorial group.

Results of the Q-mode cluster analysis revealed three clusters of stations similar with regard to foraminiferal parameters: shallow, relatively deep, and deep (Fig. 2; Yanko-Hombach et al., 2013).

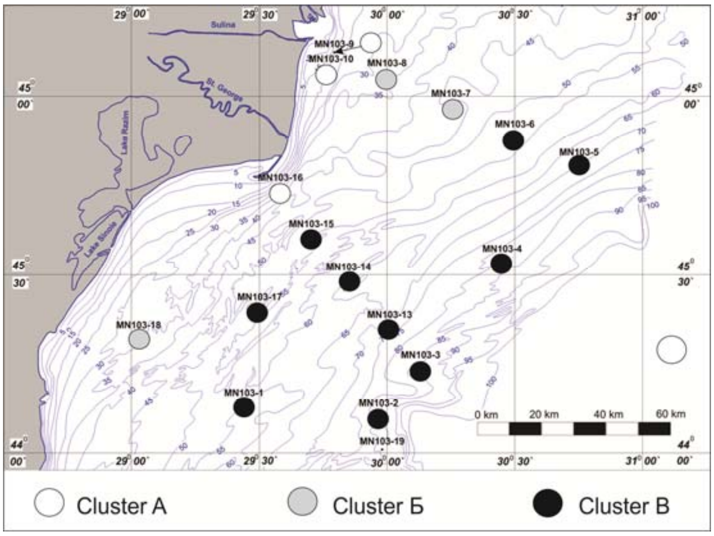

Figure 2. Map showing the spatial distribution of sample localities falling within the three clusters obtained by cluster analysis and multidimensional scaling: A – shallow (17.5–24.6 m, salinity 17.8–18 psu), B – relatively deep (33.6–46 m, 18.2–18.3 psu), and deep (50.4–80.0 m, 18.2–18.9 psu), with the dominant species *Ammonia tepida*, *A. compacta*, and *A. ammoniformis*, respectively.

The distribution of grain-size fractions in surface sediments is extremely uneven (Fig. 3).

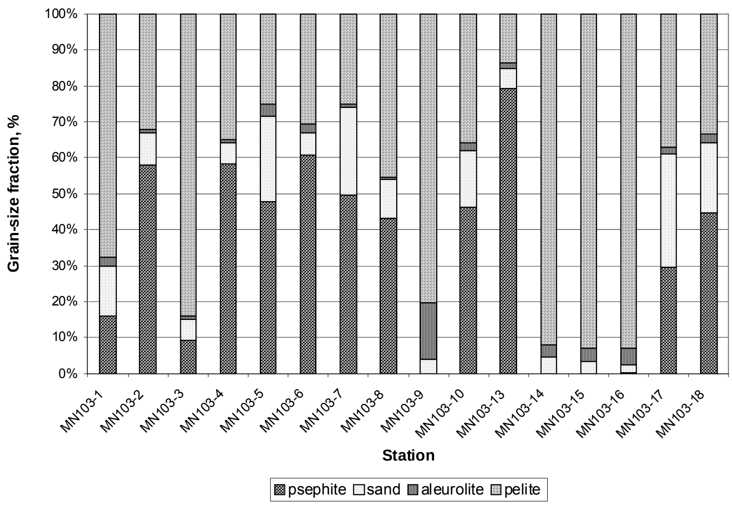

Figure 3. Distribution of grain-size fractions in the uppermost layer (0–2 cm) of bottom sediments.

Psephites are present at most of the stations and make up to 79% of the sediments. They are represented mainly by shells and detritus of *Mytilus galloprovincialis* and *Modiolus phaseolinus* that form coquina in the east and southeast of the study area at water depths of 40–80 m.

Sand content does not exceed 31%. A submerged band of deposited sand in the form of a tongue extends southeastward from the mouth of the St. George arm as far as isobath –75 m, and a solitary underwater accumulation of sand was laid down at a depth of about 20 m just off the coast of the Sulina arm. Under the microscope, the sands are composed primarily of grains of quartz, feldspar, mica, heavy minerals, and a small admixture of biogenic material (detritus, shells of foraminifera and ostracods).

The same areas are confined by silty and pelitic sediments. While silt dominates in front of the Sulina mouth, pelites are localized in front of the St. George mouth with a content of 89% and 70%, respectively. Almost everywhere in front of the Danube delta, the surface of the sediment is covered by secondary warp representing the result of geochemical flocculation.

Environmental parameters were measured as follows: In the bottom water, Tr ranged between 2 m (St. MN103-9, –17.5 m) and 12.5 m (St. MN103-3, –80.5 m); S – between 17.8 psu (St. MN103-9, –17.5 m) and 18.9 psu (St. MN103-3, –80.5 m); U – between 29.6 mSm/cm (St. MN103-9, –17.5 m) and 31.1 mSm/cm (St. MN103-3, –80.5 m); T°C – between –6.9°C (St. MN103-9, –17.5 m) and 10.9°C (St. MN103-3, –80.5 m) [the increase in temperature with depth but not vice versa is due to the fact that sampling was performed in early spring when the shallow water did not heat up enough and was cooler compared with water at depth –80.0 m]; DO – between 4.05 mg/l (St. MN103-3, –80.5 m) and 9.21 mg/l (St. MN103-6, –54.7 m); SI – between 36.5% (St. MN103-3, –80.5 m) and 78.7% (St. MN103-6, –54.7 m); pH – between 8.1 (St. MN103-18, –34.5 m) and 8.65 (St. MN103-4, –78.0 m); Eh – between 93.0 mV (St. MN103-14, –61.5 m, located in front of the St. George discharge point) to 258 mV (St. MN103-2, –67.0 m, located on the outer shelf beside the river discharge); PO_4^{-3} – between 0.01 mg/l (St. MN103-18, –34.5 m) and 0.22 mg/l (St. MN103-1, –58 m); SiO_2 – between 0.43 mg/l (St. MN103-16, –24.6 m) and 1.13 mg/l (St. MN103-3, –80.5 m). In the bottom sediments, C_{org} ranged from 2.034% (St. MN103-16, –24.6 m) to 4.39% (St. MN103-6, –54.7 m); $CaCO_3$ – from 9.126% (St. MN103-9, –17.5 m) to 44.38% (St. MN103-7, –46.0 m); C/N ratio – from 8.311 (St. MN103-8, –33.6 m) to 11.43 (St. MN103-3, –80.5 m); $\delta^{15}N$ – from 4.936 (St. MN103-8, –33.6 m) to 6.35 (St. MN103-1, –58 m).

Factor analysis of environmental parameters revealed three main factors F-1, F-2, and F-3, with total dispersion of eigenvalues of 89%. This shows that the obtained results are statistically significant. The contribution of each factor to the total dispersion of data was 48.2%, 25.8%, and 14.6%, respectively. Their position of the three factors in the plane of Factor 1 x Factor 2 is shown in Fig. 4.

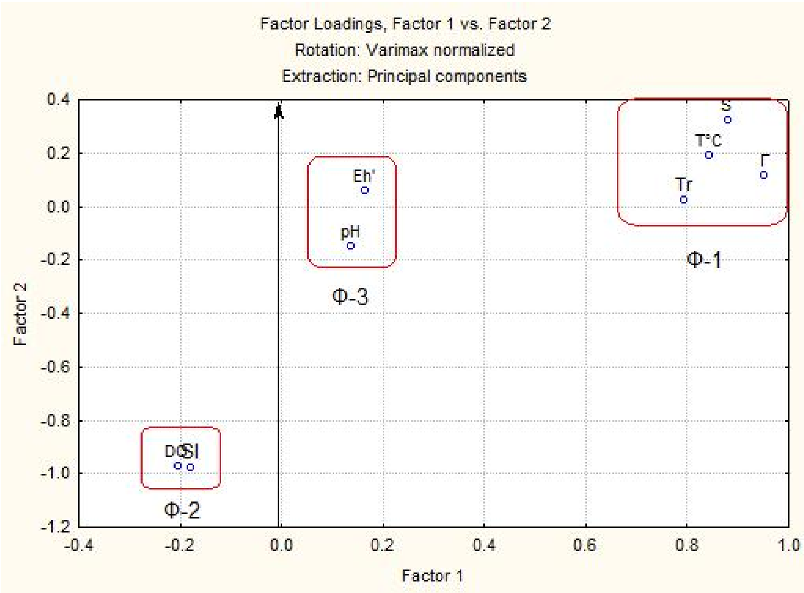

Figure 4. 2D diagram of factor analysis showing position of the three factors in the plane of Factor 1 x Factor 2.

The most powerful is F-1. It is positively correlated with D, Tr, S, U, T, SiO_2, $CaCO_3$, C/N and negatively with the aleurolite fraction. F-2 is positively correlated with DO, SI, and negatively with SiO_2. The least powerful factor is F-3, which is positively correlated with Eh and SO.

Factor 1 is a distance from the shore or water depth—the farther from the shore, the deeper and the higher the salinity and the more closely related electrical conductivity, and hence the weaker freshening influence of the Danube.

Positive correlation of F-1 with SiO_2 shows more intensive accumulation of SiO_2 on the outer shelf. This is in a good agreement with analytical measurements of SiO_2 in the water column, which also increases toward the sea bottom. The C/N ratio indicates processes that take place with organic matter on its way from the surface to the bottom and further burial. Values of C/N between 4 and 10 indicate a marine genesis of organic matter (Meyers, 1994) as in our study where C/N varies between 8.3 and 11.5. The main source of SiO_2 is diatoms, frustules of which are much more abundant in bottom sediments of the outer shelf compared to the inner one.

Positive correlation of F-1 with $CaCO_3$ ($r = 0.52$) indicates an increase in the amount of carbonate material with water depth. The positive correlation of $CaCO_3$ with psephite fraction ($r = 0.57$) speaks in favor of a biogenic origin for the psephites (by mollusk shells). Areas of distribution for the psephites identify the most favorable conditions for mollusk survival, and these are located alongside the Danube river discharge.

Negative correlation between F-1 and the aleurolite faction ($r = –0.62$) indicates distance from the shore or water depth. The latter plays an opposing role in the accumulation of fine-grained material. This contradicts the classical model of sedimentation. According to that model, accumulation of fine-grained material increases, not decreases, with depth and/or low hydrodynamic activity. In our case, the main source of fine-grained material is the Danube. Therefore, the areas of fine-grained accumulation are located in front of the Sulina and St George mouths (Fig. 5).

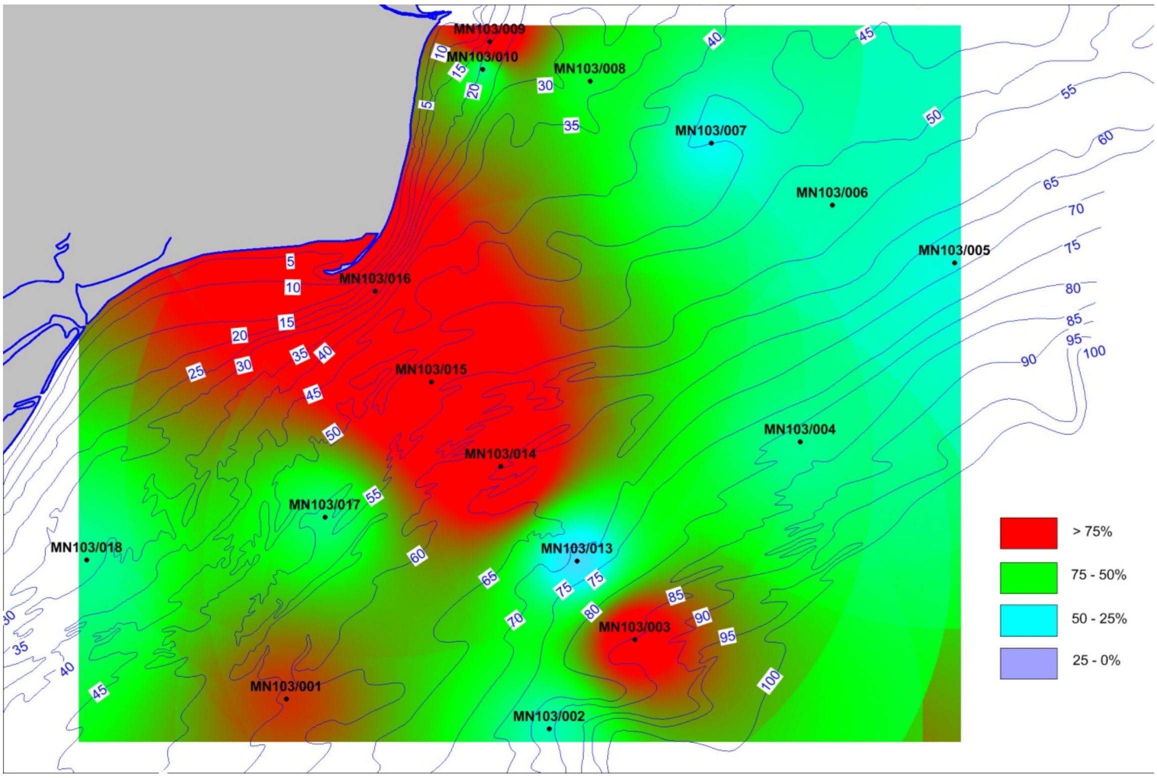

Figure 5. Spatial distribution of the pelite fraction in bottom sediments of the Black Sea Romanian shelf.

Negative correlation of $CaCO_3$ with the pelite fraction (r = –0.51) shows that carbonate material does not participate in the accumulation of this fraction. Together with the dominance of pelites in the prodelta, it speaks in favor of the formation of a geochemical barrier with intensive development of the processes of abiogenic flocculation leading to the accumulation of pelites.

Factor 2 most likely relates to eutrophication of the water column. Its effect increases towards the bottom. It can be seen from the negative correlation of SiO_2 with DO and SI (r = –0.65; –0.68, respectively) and the positive correlation with C/N (r = 0.61). Decrease in DO can be explained by its utilization by decaying diatom algae—the more algae, the lower the oxygen content and the higher the content of organic matter, and consequently eutrophication of the water column. Judging by the uneven distribution of DO and SiO_2 in the bottom water, the eutrophication has a spotty pattern.

Factor 3 seems to represent anthropogenic contamination of bottom water by organic matter discharged by the Danube. This is supported by closely related values of Eh and pH, which characterize the state of the water. Fresh water lowers the pH values of seawater while anthropogenic pollution enriches it with organic matter.

Correlation of the frequency of occurrence of the main species of foraminifera with F-1, F-2, and F-3 shows that each species or group of species can be used as an indicator of a certain state of benthic ecosystems of the Romanian part of the Black Sea.

Conclusions

Fifteen species are indicated. Their quantitative characteristics and the restructuring of their assemblages was found to correlate with hydrological and geochemical parameters of the bottom water and sediments as well as grain-size data, and it enabled the identification of three main factors influencing the environmental state of bottom ecosystems. They are as follows: (1) distance from the shore and related parameters (salinity, transparency, water temperature); (2) eutrophication of the bottom water, and (3) pollution of the bottom water by organic matter discharged from the continent. Benthic foraminifera along with lithology of the bottom sediments permitted an evaluation of the degree of influence from environmental parameters on the state of bottom ecosystems, and they facilitate the tracing of the spatial distribution of Danube freshwater discharge near the sea bottom.

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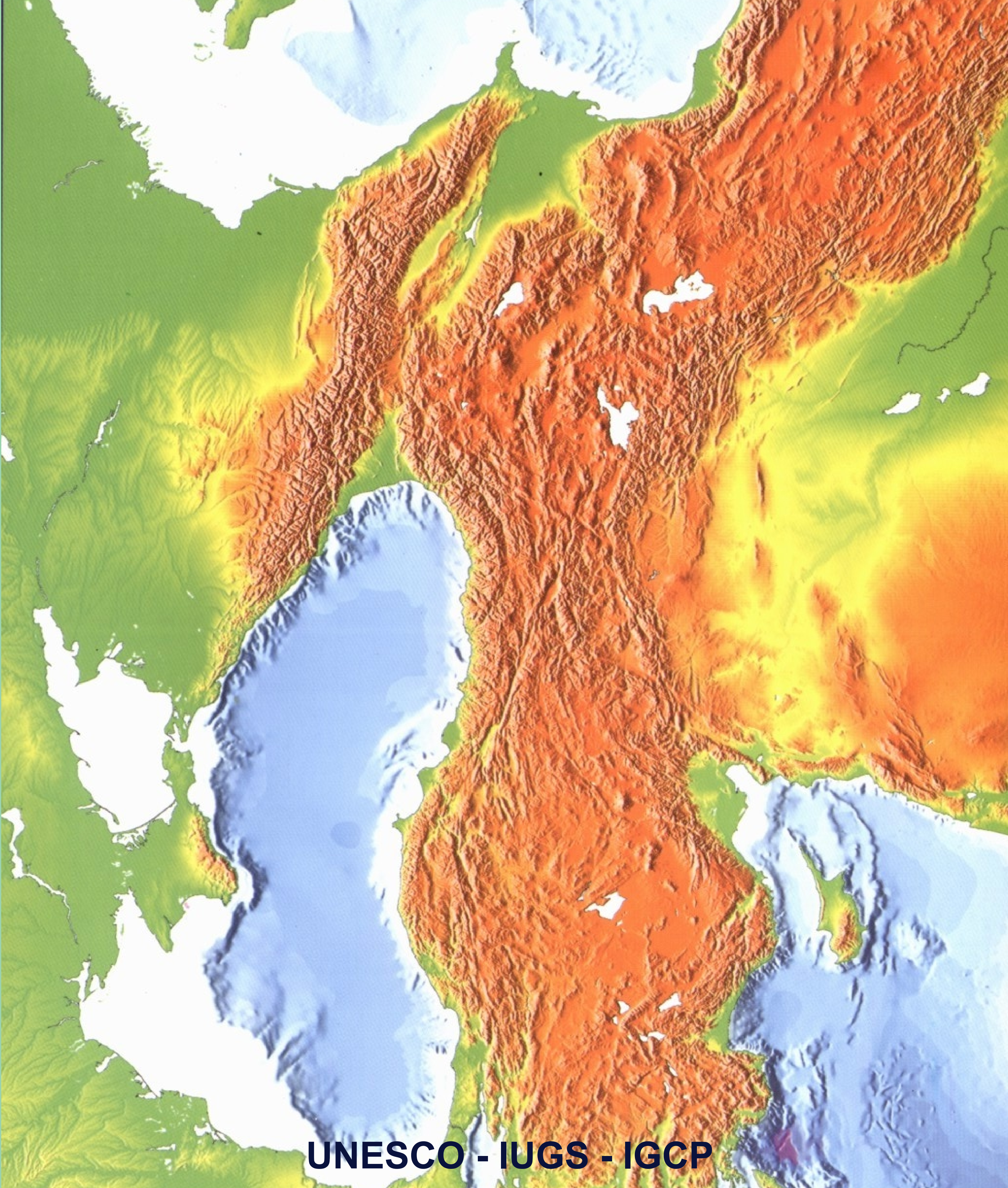

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